



Interbull Centre

INTERBULL CENTRE

**Department of Animal Breeding and Genetics
Swedish University of Agricultural Sciences - SLU**

Ulls väg 26, Box 7023, 750 07 Uppsala, Sweden

Phone: +46(0)18-67 2098

www.interbull.org



The Interbull Centre is the operational unit of the ICAR permanent sub-committee Interbull.



The Interbull Centre holds the status of European Union Reference Body for Zootechnics (Bovine Breeding), and is a designated European Union Reference.



The Interbull Centre is ISO 9001:2008 certified.





INTERBULL CENTRE

Table of Contents

1. Executive Summary	4
2. Swedish University of Agricultural Sciences (SLU)	5
3. Department of Animal Breeding and Genetics (HGEN)	8
4. The Interbull Centre.....	14
5. Quality Management and ISO 9001 Certification.....	23
6. The Interbull Centre's Computing Infrastructure	24
7. The Interbull Centre's Activities	28
8. International Scope	38
List of Abbreviations.....	46

Photo's and diagrams courtesy of SLU Media Bank, ICAR, Lidia Chavinskaia and Toine Roozen.

1. Executive Summary

The Interbull Centre is a section of the Department of Animal Breeding and Genetics (HGEN) of the Swedish University of Agricultural Sciences (SLU), and acts as the operational unit for Interbull and Interbeef, a permanent subcommittee and a working group of the International Committee for Animal Recording (ICAR), respectively.

Moreover, the Interbull Centre holds since 1996 the status of European Union Reference Body responsible for collaborating in rendering uniform the testing methods and the assessment of the results for pure-bred breeding animals of the bovine species, and is the designated European Union Reference Centre (EURC) responsible for the *“scientific and technical contribution to the harmonisation and improvement of the methods of performance testing and genetic evaluation of purebred breeding animals of the bovine species”* as of 1 November 2018.

The Interbull Centre has the capacities and expertise as an International Central Data Hub, enabling International exchange of data and Quality Control.

For over 20 years, the Interbull Centre is responsible for the monitoring of the national genetic evaluation of cattle. The Interbull Centre team currently consists of 9 members of staff and conducts international genomic and genetic evaluations for beef and dairy cattle in 35 countries. For several years we have distributed more than half a billion international estimated breeding values based on these genetic evaluations. The number of breeding values for genomic evaluations is quickly increasing and is now over 80 million a year.

As such Interbull supports the dairy and beef industry with accurate genetic information on bulls of the major dairy and beef breeds for use by importers and exporters, thereby facilitating selection of the best genetics worldwide.

This document is testament to the expertise, infrastructure and international network that the Interbull Centre has built up in the two decades since its inception. The Interbull Centre:

- Is an internationally recognised institution; it provides genetic information services and applied research for improvement of livestock to a worldwide network;
- Fulfils successfully its duties as the EU Reference Body for Zootechnics for 20 years;
- Is embedded within the Swedish University of Agricultural Sciences, and as such is able to deal with topics at the highest scientific level, while also being supported by the Swedish State;
- Is embedded within the ICAR community as it is the Operational Unit of ICAR's permanent Sub-Committee INTERBULL, and its Working Group INTERBEEF;

The Interbull Centre and its staff fulfil such a central role within the International dairy and beef genetic evaluation services, and perform its services according to ISO 9001:2008 principles.

2. Swedish University of Agricultural Sciences (SLU)

The Swedish University of Agricultural Sciences (Sveriges lantbruksuniversitet, SLU) was founded in 1977 by merging the erstwhile Agricultural, Forestry and Veterinary University Colleges, the Veterinary School and the School for Forest Management.

SLU's mission statement is: "SLU develops the understanding and sustainable use and management of biological natural resources. This is achieved by research, education and environmental monitoring and assessment, in collaboration with the surrounding community." The university's scientific profile is reflected in two main focuses that are in response to many of the major global challenges:

- A bio-based economy
- Environment, health and quality of life.



SLU was ranked 4th worldwide and 2nd in Europe in the March 2017 QS World Ranking of universities in Agriculture and Forestry. This ranking is based on academic and employer reputation, research paper citation and the h-index (a way of measuring both the productivity and impact of published work).

Table 2.1: SLU in figures (2016).

	SLU	Department of Animal Breeding and Genetics	Interbull Centre
Number of Employees	2774	55	9
Number of Professors	214	10	1
Turnover (2016)	3 Billion SEK	67 Million SEK	11 Million SEK

2.1. Organisational Structure

SLU has four faculties:

- Landscape Architecture, Horticulture and Crop Production Science
- Natural Resources and Agricultural Sciences
- Forest Sciences
- Veterinary Medicine and Animal Science

Veterinary Medicine and Animal Science have been unified in one faculty at SLU since 2004. The Interbull Centre is a section within the Department of Animal Breeding and Genetics at the Faculty of Veterinary Medicine and Animal Science.

At SLU, the Faculty of Veterinary Medicine and Animal Science is responsible for research and education on healthy animals and animals with disease. This is done with a sustainability perspective in which ecological/environmental, economic and societal impacts are considered. One of the faculty's objectives is that the faculty should be the obvious academic collaborative partner within the faculty's areas of expertise. The vision of this faculty is a "sustainable use of animals for global food supply, public health, and with the well-being and health of the animals themselves in focus."

2.2. Ultuna and the Centre for Veterinary Medicine and Animal Science

SLU is located in 35 locations across Sweden. At 6 of these locations, research concentrates on agriculture and animal husbandry. The University's main campuses are in Uppsala, Alnarp, Umeå and Skara. Campus "Ultuna", 6 kilometres South of Uppsala, is SLU's largest campus, with some 2000 employees and 2500 students, and this is where the University's management and central administration are located. Most of the Faculty of Veterinary Medicine and Animal Science is located in Ultuna.

Ultuna forms an inspiring environment with a well-functioning infrastructure and excellent resources for strong, interdisciplinary research approaches and information exchange for the benefit of animals, the environment and society.

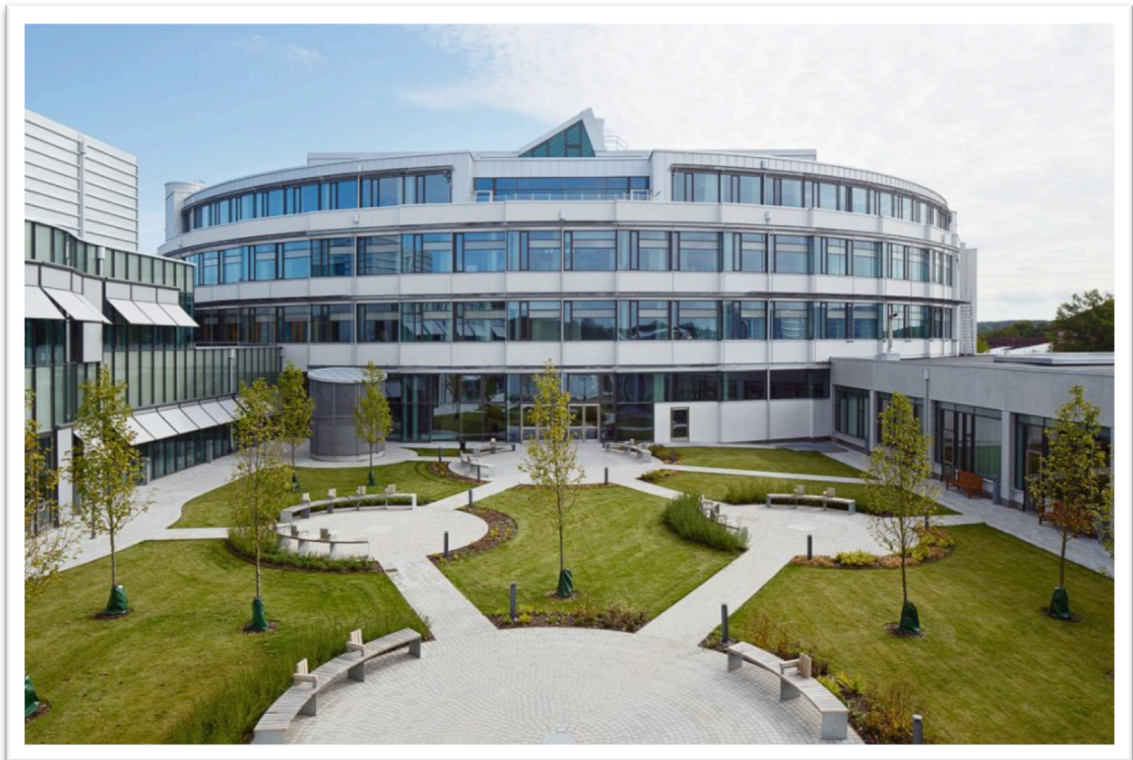
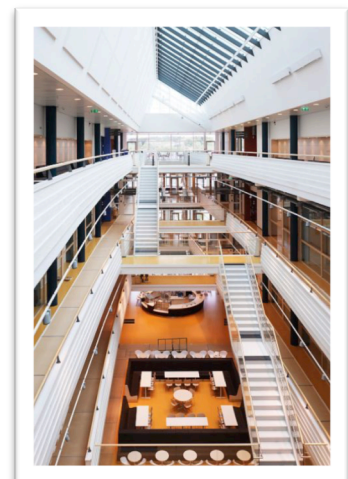


Figure 2.2 (above) and Figure 2.3 (below, right): Centre for Veterinary Medicine and Animal Science

Since 2014, the majority of Swedish veterinary medicine and animal science research and education has been housed together with Sweden's only university hospital in one of the newest buildings on Ultuna: Centre for Veterinary Medicine and Animal Science (VHC), which was inaugurated in September 2014. VHC has effective and well-functioning facilities, including laboratories and animal units for experimental studies, and is one of Ultuna's main components. The working environment creates openness and opportunities for contacts across department borders and spontaneous meetings. VHC is designed to meet extreme requirements for durability, hygiene standards, infection control and ease of cleaning. Fittings and building



materials meet high environmental standards. VHC has an environmental management system that fulfils the requirements of SS-EN ISO 14001 with respect to: *“education, research, environmental monitoring and assessment and also animal hospital”* (Certificate no. 5892M).

The Interbull Centre, being a section within the Department of Animal Breeding and Genetics at the Faculty of Veterinary Medicine and Animal Science is located within VHC.

SLU’s Swedish Livestock Research Centre Lövsta is located near Ultuna. It was opened in 2012, and provides opportunities for state-of-the art animal studies through animal facilities that are similar to modern commercial farms. As such, the Swedish Livestock Research Centre Lövsta is an important complement to VHC including stables for dairy cows, pigs and poultry.

3. Department of Animal Breeding and Genetics (HGEN)

The Department of Animal Breeding and Genetics (HGEN), is one of eight departments within the Faculty of Veterinary Medicine and Animal Science, SLU. At HGEN we work with research and education within molecular genetics, bioinformatics, quantitative genetics and applied genetics - in livestock, sport and companion animals. The vision of HGEN is “Improved use of animal genetic resources” and the aim is to do excellent research and education, and interact with society within Animal Breeding and Genetics, and thus contribute to a sustainable development of our society.

HGEN is led by two Heads of Department (joint leadership), who, administratively, are supported by the “Administration” section. For educational activities HGEN employs two Directors of Studies.

Four faculty professors are working together for the scientific development at the department. The range of activities is reflected by the department’s six scientific sections. There are four research sections: “Molecular Genetics”, “Bioinformatics”, “Quantitative Genetics” and “Applied Genetics”, and two service sections: “SLU Biobank” and “Interbull Centre”.

The Molecular Genetics section also includes a laboratory for contract research, “HGEN Lab”. At the HGEN Lab, various molecular genetic tests are performed, e.g. for disease and coat colour alleles. Pedigree tests - predominantly for horse - are also carried out.

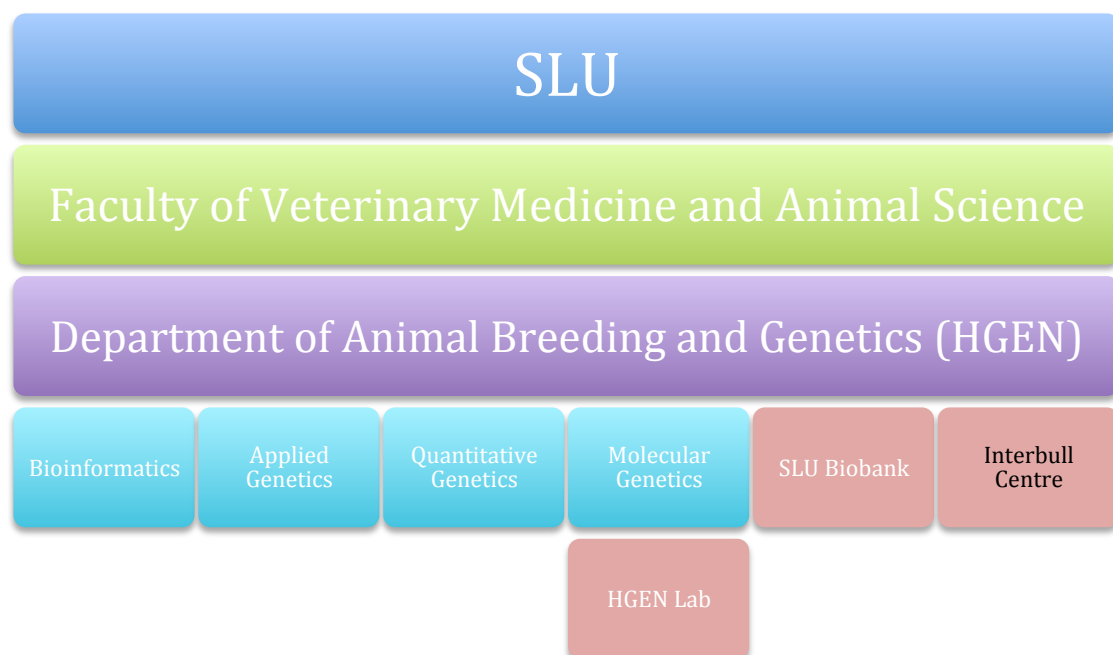


Figure 3.1: Organisational structure of the Department of Animal Breeding and Genetics (HGEN).

SLU Biobank serves the whole of SLU. It provides handling and storing of biological material from all kinds of organisms except humans and it is also a knowledge bank with expertise in data collections, sampling, handling and storage of biological material.

The Interbull Centre is described in detail in Chapter 4.

Each Section is led by a Section Leader, with responsibility for finance and human resources, while each Section leader is a member of HGEN's Advisory Board. Heads of Department, Directors of Studies, recruited professors and a representative for the PhD students are also members of HGEN's Advisory board, which supports the Heads of Department in strategically important issues.

3.1. HGEN Administration

HGEN's Administration section provides support for financial, human resources, information technology and educational activities to the HGEN, and the sections within HGEN. In addition to the Heads of Department and the Head of Administration, the HGEN Administration section includes two Directors of Studies, three administrators and IT and web support staff.

The financial administration includes keeping accounts, invoicing and handling of payments. The financial administrator is responsible for providing support to the department and the different sections in issues concerning financial administration and reporting, and coordinating and providing quality assurance of all work at the department and the sections relating to accounts and finance. The financial administrator also gives support in providing necessary background information for decisions.

HR administration includes handling accounting entries and reimbursements, preparing reports and monitoring absences, leave of absences, illness and travel expenses. The HR administrator gives support for recruitments and management of employment procedures and in providing necessary background information for decisions.

HGEN administration provides the departmental information to SLU's respective central departments responsible for finance, HR and IT, while these central departments provide the relevant support to HGEN administration.

3.2. HGEN Personnel

HGEN employs at present (March 2017) 31 researchers-teachers, 13 PhD students, and 18 Technical and Administrative members of staff. The Department employs four faculty professors with a distinct area of responsibility, and 6 professors with a personal chair.

Faculty Professors:

- Prof. Göran Andersson – faculty professor Molecular Animal Genetics
- Prof. Eric Bongcam-Rudloff – faculty professor Bioinformatics
- Prof. DJ de Koning – faculty professor Animal Breeding
- Prof. Erling Strandberg. – faculty professor Animal Breeding (statistical genetics)

Professors with personal chair:

- Prof. Britt Berglund – personal chair Animal Breeding, working mainly on cattle breeding
- Prof. Hossein Jorjani – personal chair Animal Genetics, working mainly on genetic evaluation of cattle
- Prof. Nils Lundeheim – personal chair Animal Breeding, working mainly on pig breeding
- Prof. Lotta Rydhmer – personal chair Animal Breeding, working mainly on breeding for

sustainable production

- Prof. Leif Andersson (adj. prof., 20% at HGEN) – Molecular Genetics
- Prof. Lars Rönnegård (guest prof., 20% at HGEN) – Statistical Genetics

Since 1 January 2017 Prof Lotta Rydhmer and Prof DJ de Koning share the role of Head of the Department of Animal Breeding and Genetics (HGEN). Until assuming this role, Profs Rydhmer and de Koning were the respective leaders of HGEN's Sections for Applied Genetics and Quantitative Genetics.

Prof. Lotta Rydhmer is professor in animal breeding. The focus of her studies is related to traits important for animal welfare and traits related to environmental impact in several species. Prof. Rydhmer works with research and education on animal breeding and genetics, mainly breeding for sustainable production, and has performed many genetic studies of reproduction and behavioural traits, and relations between reproduction and production traits, especially in pigs. From 2007-2009 she was Vice-Dean at the Faculty for Veterinary Medicine and Animal Science. Lotta has been the Swedish representative at the Animal Task Force for one year and she is member of the council of the European Federation of Animal Science (EAAP). Since 2012 she is deputy program director of the interdisciplinary research platform "Future Agriculture - livestock, crops and land use" at SLU. Lotta is also member of the Swedish Gene Technology Advisory Board, since 2011.

Prof. DJ de Koning's research interests are mainly in the field of dissecting the genetic basis of variation in complex traits and use of this information in breeding programs, covering predominantly the traditional livestock species but currently expanding into aquaculture. He has ongoing research on bone strength in laying hens with several national and international collaborators. His PhD students work on a range of topics including fertility in dairy cattle, use of sequence data in selection and development of the immune system in relation to colostrum uptake in cattle. Prof. de Koning is in the management team of "*Mistra Biotech*" - an interdisciplinary research programme focusing on the use of biotechnology for sustainable and competitive agriculture and food systems. In this program he leads the research area on "Refined tools for molecular breeding". DJ is deputy editor-in-chief of *G3-Genes/Genomes/Genetics*, an Open Access Journal of the Genetics Society of America. He is also associate editor for Genetics and has had previous editorial roles at Heredity, Animal Genetics, and Animal. Prof. De Koning is also member of the CGIAR's new cross-commodity Platform called Excellence in Breeding Platform, and has served on several grant panels for the BBSRC (United Kingdom) and he is a member of the Research Oversight Committee for two large projects in Genome Canada. From 2007 until 2015 he was a board member of the Genetics Society (UK), with the last four years as a member of the executive committee.

Prof. Erling Strandberg was the Head of Department until 2013. His research includes cattle and sheep breeding in low income countries and genetic evaluation of health traits. Since Interbull's inception, the role of the Interbull Secretary has been held by a HGEN professor; from 1983 until 2011 by Prof Jan Philipsson, and then, until 2015 by Prof. Erling Strandberg. Since 2015, the functions of the Secretary have been assumed by the Interbull Centre Director.

Prof. Hossein Jorjani was from 2014-2016 the Head of the Department of Animal Breeding and Genetics (for 50% of the time). He is now full-time employed as the Interbull Service Manager with activities at the Interbull Centre (more details in Chapter 4 “Interbull Centre Personnel”).

3.3. Education at HGEN

HGEN is involved in many BSc, MSc and PhD courses in several education programmes, which are managed by two Directors of Studies. All researchers take part in teaching and in 2016 the number of fulltime HGEN students was 45. Many researchers are also supervisors for PhD students. Five to six PhD students defend their thesis per year. PhD courses address topics such as Genome analyses, Bioinformatics, R-programming, and SAS-programming. HGEN is involved in the Nordic Forestry, Veterinary and Agricultural University Network (NOVA Network), which provides PhD-courses in Animal breeding and genetics, including topics such as Scientific writing, Genetic epidemiology, Sustainability concept in animal breeding and Statistical methods for animal breeding.



Erasmus
Mundus

HGEN runs - together with Wageningen University, Aarhus University and AgroParisTech - the *European Graduate School in Animal Breeding and Genetics* (“EGS-ABS”, www.egsabs.eu); an international Doctorate programme shaped to train the new generations of animal breeders to meet the challenges of the increasing food demand while reducing the impacts on environment and biodiversity. EGS-ABG is an Erasmus Mundus Joint Doctorate, a label awarded by the European Union for outstanding quality courses.

Interbull Centre members of staff have been main or co-advisors for many post-graduate students that worked with research problems of direct relevance to international genetic evaluation. August Sigurdsson, Freddy Fikse, Thomas Mark, and Mohammad Ali Nilforooshan received their PhDs within the Interbull Centre. Approximately 20 students graduated with an MSc or BSc with an Interbull Centre member of staff as their main advisor.

3.4. Research at HGEN

The research at HGEN is performed along the whole chain from basic research via applied research to contract research. Researchers are encouraged to move along that chain, to work across species and when relevant also across disciplines. Thus the structure with six sections described above is mainly a structure for administrative purposes; in practice researchers-teachers cooperate across sections. A strong contact and dialogue with stakeholders is important for HGEN and these contacts are often related to specific species, e.g. dairy farmers or dog owners.

The research performed at HGEN is based on various types of data; new data collected from the Swedish Livestock Research Centre Lövsta, existing data from the Lövsta data base, new field data collected in commercial herds, existing field data from data bases belonging to e.g. breed organisations, and simulated data.

A large part of the research and contract research performed at HGEN is highly relevant for the Interbull Centre. Some examples of recent and on-going scientific studies at HGEN are:

- Increased profitability by using new breeding tools in dairy herds (in cooperation with a Danish University)
- Development of a novel selection strategy using genomic data in crossbred sows to improve maternal traits and longevity (in cooperation with a Norwegian breeding organisation)
- Calculation of total genetic merit index for Swedish sheep breeding; High animal welfare in organic lamb production through breeding
- Organic Dairy Health - Improving animal health and welfare in organic cattle milk production through breeding and management (EU project)
- Understanding production systems and genetic diversity of the Creole cattle that contribute to food security in Bolivia
- Performance and adaptability of Ankole cattle in Rwanda
- Forage efficient cows - good for the cows and the environment; Find the forage efficient cows and increase profitability
- High milk production reduces ability to show oestrus – how to get pregnant cows?
- Old bulls and new tricks – learning from effects of previous selection
- Improved breeding for fertility in Nordic dairy cows by using new recordings and novel traits (Nordic project)
- Inclusion of new traits in the genetic evaluation of horses
- GenTORE: Genomic Management Tools to Optimise Resilience and Efficiency across the Bovine Sector (EU project)
- ReDiverse: Biodiversity within and between European Red dairy breeds - conservation through utilisation (EU project)
- Identifying mutations affecting milk coagulation properties in Swedish Red Dairy cattle
- Developing machine learning approaches for future animal breeding and management
- Refined models for genomic selection and implement these in user-friendly tools
- Detect and evaluate genetic markers for bone strength in laying hens
- Genetic variation in natural antibodies in colostrum and the uptake of natural antibodies by the calf.

HGEN published, during the period 2014-2016, 459 publications of which 230 in peer reviewed journals. .

Fruitful cooperation with several breed and breeding organisations in Sweden and other Nordic countries for many years makes it possible for HGEN researchers to use data from national data bases and to play an active role in the development of performance testing and genetic evaluation. Recording of new traits has been initiated; genetic parameters for these traits estimated and the new traits have been included in the genetic evaluation. An example of this is in-line recordings of milkability that is now included in the Nordic Total Merit (NTM) breeding value for milkability, and recently also udder coordinates in the genetic evaluation for udder traits.

In addition to the contract research performed at HGEN lab (molecular gene tests and pedigree tests), several researchers carry out contract research in collaboration with breed organisations. Two examples: The genetic evaluation of Swedish Warmblood Horses is done at HGEN; A HGEN researcher has been acting as an advisor for a pig breeding organisation for many years, mainly working with the performance test and the genetic evaluation of pigs.

Cow genotypes have been collected together with detailed phenotypic data since 1994 at SLU's previous research herd Jälla, and from 2012 at the new research facilities for dairy cattle at Lövsta. This data has amongst others been used in the EU FP7 project RobustMilk (Grant Agreement 211708) where a data bank from four countries was compiled to perform genome wide association studies for e.g. progesterone based fertility traits. In another study this data was used together with recordings from Denmark and Finland, with the aim of developing a breeding value for feed efficiency of dairy cows to be included in the Nordic Total Merit Index.

4. The Interbull Centre

Organisationally the Interbull Centre is a part of HGEN. The Interbull Centre provides international genetic information services. It was formally established in 1990.



Figure 4.1: Interbull Centre's offices

4.1. History of Interbull and the Interbull Centre

Interbull was formally established in 1983 as an international network of scientists from academy and industry working with questions related to the exchange of genetic material across country borders. The network concentrated on the exchange of ideas and information about the best practices of national performance testing, national genetic evaluations, and conversion of foreign breeding values to domestic breeding values. In 1988 Interbull became a permanent sub-committee of ICAR (International Committee for Animal Recording).

Interbull Objective

To support the dairy industry with accurate genetic information on bulls of the major dairy breeds for use by importers and exporters, thereby facilitating selection of best genetics for different countries, environments or breeding goals.

In late 1980's Interbull realised the need for an operational unit, and after a careful bidding process, Interbull decided in 1990 to contract the establishment of its operation unit, the Interbull Centre to the Department of Animal Breeding and Genetics (HGEN), Swedish University of Agricultural Sciences (SLU). The original decision to choose Uppsala as the location of the Interbull Centre came down to its reputation for providing a good service and Sweden's reputation as being internationally independent and thus acceptable to the membership of Interbull. From the beginning Interbull acted as the Steering Committee of

the Interbull Centre. Since 1988 the Interbull Steering Committee is composed of 9 members with representative from different regions of the world. The role of the Interbull Steering Committee is to set strategy, priorities, work plans and budgets.

Interbull Milestones

1983	Interbull Committee founded by IDF, EAAP and ICAR, and supported by FAO after a meeting at WCGALP in Madrid 1982
1988	Interbull becomes a permanent sub-committee of ICAR with its own Steering Committee
1990	Interbull Centre established at SLU, Uppsala
1995	First fully user-paid International Routine Genetic Evaluation
1996	Interbull Centre designated as EU Reference Body for Bovine Breeding
2011	First International Genomic Evaluation

In the first few years, the Interbull Centre worked exclusively with the development of scientific and technical methods of the international genetic evaluation, and concentrated on the production traits (milk, fat, and protein yield) in the two important breeds of Holstein and Ayrshire, mainly from the Nordic countries. During 1994/1995 these developments reached a point where IB-SC recognised the fact that the methodology was mature to be put into routine practice for a wider range of countries. Thus, after extensive test evaluations in 1994, the first official international genetic evaluation of production traits, in Holstein and Ayrshire populations, from 9 countries was performed at the Interbull Centre in 1995.

Sweden joined the European Union in 1995, and in 1996 the Interbull Centre was designated as the European Union's Reference Body "responsible for collaborating in rendering uniform the testing methods and the assessment of the results for pure-bred breeding animals of the bovine species". It has since provided assistance to the European Commission in issues related to bovine breeding and genetics.

4.2. Interbull Centre Personnel

Interbull Centre staff are employed by the Department of Animal Breeding and Genetics (HGEN) of the Swedish University of Agricultural Sciences (SLU), and consists of:

- Toine Roozen (MSc, MBA), Director
- Hossein Jorjani (DVM, PhD, Professor), Senior Genetic Data Analyst, Service Manager
- Haifa Benhajali (PhD), Genetic Data Analyst - Genetics
- Eva Hjerpe (MSc), Genetic Data Analyst - Genetics
- Valentina Palucci (MSc), Genetic Data Analyst - Genetics, Quality Manager
- Joanna Sendek (PhD), Genetic Data Analyst - Genetics
- Marcus Pedersén, Genetic Data Analyst – IT; Systems Administrator
- VACANCY, Genetic Data Analyst – IT; Programmer, Systems Administrator
- Carl Wasserman, Genetic Data Analyst – IT; Systems Developer, IT Coordinator
- Louise Simann (BA), Administrator

The organisational structure is provided below, followed by an introduction to the members of staff.

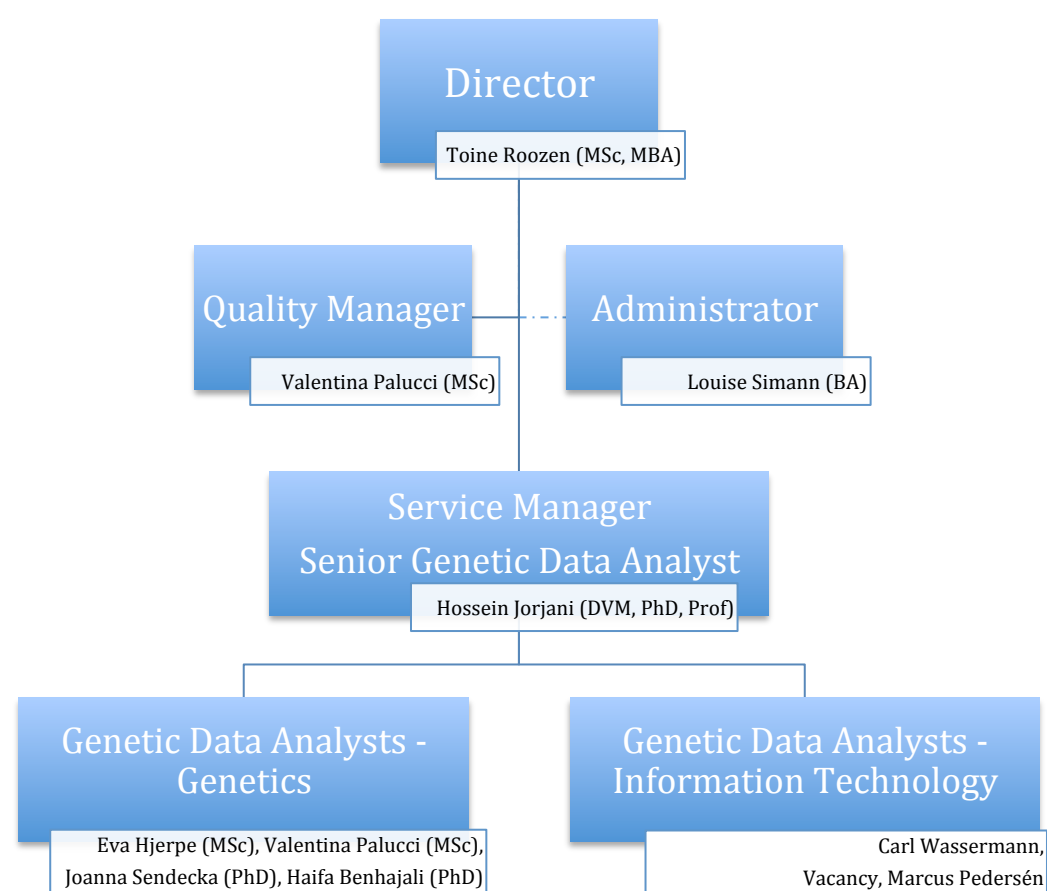


Figure 4.1: Organisational structure at Interbull Centre



Figure 4.2: Interbull Centre staff

4.2.1. Director

Mr Toine Roozen, Interbull Centre Director, was born and raised in the Netherlands and graduated from Wageningen University with a BSc and MSc in Animal Breeding and Genetics.

While working in the United Kingdom, Mr Roozen also completed an Executive MBA from Saïd Business School, University of Oxford.

For the first eight years of his professional career (1994-2002), Mr Roozen held both technical and business development positions in the pig breeding industry, most notably a pan-European role in standardising the pig breeding and selection practices of the world's largest pig breeding company, and a role as Business Development Manager for PIC Europe.

From 2003 to 2015, Mr Roozen was employed by the Knowledge Transfer Network (KTN Ltd, and its predecessors 'Genesis Faraday' and 'Bioscience Knowledge Transfer Network'), which is an interdisciplinary network that provides a powerful vehicle for promoting innovation by accelerating the rate of technology transfer from research to industry adoption. During this period, Toine managed two key bio-tech related EC FP6 and FP7 projects ("*SABRE*" (Grant Agreement no. 016250), "*Quantomics*" (GA no. KBBE-2A-222664), both of which involved many researchers and consortium members as well as significant budgets, and co-founded the European Cattle Innovation Platform ("*ECIP*"), which instigated common activities of, initially, 6 European levy boards with a common interest in applied R&D and knowledge exchange, addressing dairy industry challenges. He was also responsible for training and sustainability activities in the Horizon2020 *Gene2Farm* project (GA no. 289592) until he started his role as Interbull Centre Director.

Toine commenced employment as the Interbull Centre Director in September 2015, and will hence have been in this position more than three years when the European Reference Centre is expected to commence its duties on 1 November 2018. In his role as Interbull Centre Director he has shown great leadership in strengthening the positive relationship between the Interbull Centre and the international dairy and beef cattle communities.

4.2.2. Service Manager

Dr Hossein Jorjani is professor of animal genetics at the Swedish University of Agricultural Sciences (SLU), and has been employed by SLU since 1990. Hossein has had his education in a number of countries: DVM (Tehran), Post-graduate Diploma (Glasgow), MSc (Edinburgh), and PhD (SLU, Uppsala). Hossein has been working mainly with cattle, but also with sheep, horse, and poultry.

Before joining the Interbull Centre (1996-1998), Hossein was the Swedish representative in the research group responsible for the development of Nordic animal model for the dairy cattle populations from Denmark, Finland, and Sweden.

Professor Jorjani joined the Interbull Centre in 1998 with three main responsibilities. The first responsibility was to review the national performance testing and genetic evaluations for all ICAR member countries (even those that were not participating in the Interbull Centre's activities). This work resulted in the latest Interbull Guidelines (Interbull Bulletin 28), which also appears as an independent chapter in the ICAR Guidelines. The second responsibility was to improve the methods of estimating genetic correlations across countries and traits. This work led to invention of methods to simultaneously estimate a large number of genetic correlations, and how to combine disparately estimated correlations. The third responsibility was to improve the methods of validation of performance testing and genetic evaluations at

the national level. All these three responsibilities are still part of the Interbull Centre activities on a “continuous improvement” basis. Hossein expanded his work to areas related to cow functionality (female fertility, and workability traits), and nowadays works with all traits of interest for international exchange of genetic material from dairy and beef cattle.

Hossein became R&D manager for the Interbull Centre in 2009, and service manager in 2013. Hossein was also the interim director of the Interbull Centre in 2014-2015. He is the editor-in-chief for the Interbull Bulletin, which has been publishing results of Interbull meetings since 1986, and of which the 50th edition was published in 2016.

4.2.3. Quality Manager

Valentina Palucci is a member of our team of geneticists since she joined the Interbull Centre in 2007 with a BSc in Animal Science and an MSc in Quantitative Genetics. While at Interbull Centre, Valentina qualified as an ISO 9001 lead auditor, and as our Quality Manager she oversaw the process that led to the ISO 9001:2008 certification of our quality management system. She continues to lead the process for the Interbull Centre to maintain and improve the current management system while also ensuring that new services will be accredited.

4.2.4. Genetic Data Analysts - Genetics

Our team of geneticists, Hossein Jorjani, Eva Hjerpe, Valentina Palucci, Haifa Benhajali and Joanna Sendek, share 1 DVM, 3 PhD's and 5 MSc's in Animal Science, Quantitative Genetics, Veterinary Science and Evolutionary Ecology. Although specific responsibilities are assigned, the team works in a cooperative manner rotating tasks so that the “know-how” of the different services offered by Interbull Centre is shared. Therefore, they jointly provide the services related to the verification of international data, the international genetic and genomic evaluations, and the genetic and genomic validations.

4.2.5. Genetic Data Analysts – Information Technology

The Interbull Centre's Information Technology Infrastructure is built and maintained by a team of three; Carl Wasserman, Marcus Pedersén and a third, currently vacant, position. While each has their own specialisation (Carl, systems development; Marcus, system administration; and a vacant position for a programmer), they work as a team where each can take on all activities. All technical solutions are decided as a team, implemented and documented in a structured way, so all team members will be able to handle and maintain implemented solutions. The team keeps up to date with new technologies to be able to find new ideas and technologies suitable for Interbull Centre to refine current services and add new services for better customer support and service. Main goal is to provide great service, customer support and maximum availability to all users of all systems. Activities within the IT team are coordinated by Carl Wasserman.

4.2.6. Administrator

Louise Simann joined the Department of Animal Breeding and Genetics in September 2016 with a degree in Business Administration, and with the responsibility to support the Interbull Centre, and other HGEN sections. Louise works as an administrator, dealing with financial administration as well as HR administration. Louise has extensive experience in financial and HR administration from previous work places.

4.3. Roles and Governance

Interbull Centre is strongly related with three distinct institutions:

- 1- The Interbull Centre is a section of the Department of Animal Breeding and Genetics of the Swedish University of Agricultural Sciences (SLU);
- 2- The Interbull Centre has been contracted by ICAR to be the operational unit for ICAR's permanent subcommittee "Interbull" and the ICAR working group "Interbeef";
- 3- In 1996 the Interbull Centre was designated as the European Union's Reference Body "responsible for collaborating in rendering uniform the testing methods and the assessment of the results for pure-bred breeding animals of the bovine species" (EURL-Z). As of 1 November 2018, the Interbull Centre will be the European Union's Reference Centre (EURC) responsible for the *"scientific and technical contribution to the harmonisation and improvement of the methods of performance testing and genetic evaluation of purebred breeding animals of the bovine species"* as of 1 November 2018.

4.3.1. The Interbull Centre's Role as the EURL-Z

Based on the EU Council Decision 96/463/EC, the duties of the Interbull Centre as the EURL-Z are:

- Be the documentation and information centre for the methods of testing and assessing the genetic value of pure-bred breeding animals of the bovine species for the Member States;
- Provide assistance in order to contribute to the harmonization of the various methods of testing and assessing the genetic value of pure-bred breeding animals of the bovine species;
- Provide assistance in order to permit the comparison of the results of the methods of testing and assessing the genetic value of animals in the various Member States;
- Help the bodies responsible for setting the rules for performance recording and assessing the genetic value and for publication of the evaluation results of pure-bred breeding animals of the bovine species appointed by Member States to take part in a comparison of the results of the assessment of genetic value at international level;
- Evaluate the problems of assessing pure-bred breeding animals and attempt to resolve the problems linked to the genetic assessments carried out in the various Member States.

4.3.2. The Interbull Centre's Role as the operational unit of Interbull

The Interbull roles allocated to the Interbull Centre were, and still are, to:

- Provide services in the field of international genetic evaluation of cattle, communication and research in related subjects.
- Convene, prepare and organise Interbull Business Meetings;
- Convene and organise Interbull Open Meetings;
- Arrange seminars for exchange of scientific information and practical experiences in the field of national and international genetic evaluation of bulls and also on implications for cow evaluation.
- Arrange workshops to facilitate the development of appropriate procedures for the

international genetic evaluation.

Interbull Committees

These roles have been allocated to the Interbull Centre by the Interbull Steering Committee. These roles have been detailed in the “Terms of Reference and Rules of Procedure of Interbull Sub-Committee” (www.interbull.org/ib/termsofreference). Members of the Interbull Steering Committee are representatives from different regions of the world. The Interbull Annual Meeting proposes Interbull SC representatives to the ICAR Board. The ICAR Board subsequently officially appoints the members of the IB-SC for a period of 4 years.

Since 2003 the Interbull Steering Committee is supported by two expert groups: the Scientific Advisory Committee and the Interbull Technical Committee (ITC). The objective of the SAC is to propose methodological developments that are needed to ensure the strategic direction, scientific soundness, and long-term progress of the Interbull services. The objective of the ITC is to identify and review technical issues that may be essential for providing a high quality service to countries participating in the international genetic evaluations.

The Interbull Committee structure is shown in Figure 4.3, followed by the current composition of each of the Interbull Committees.

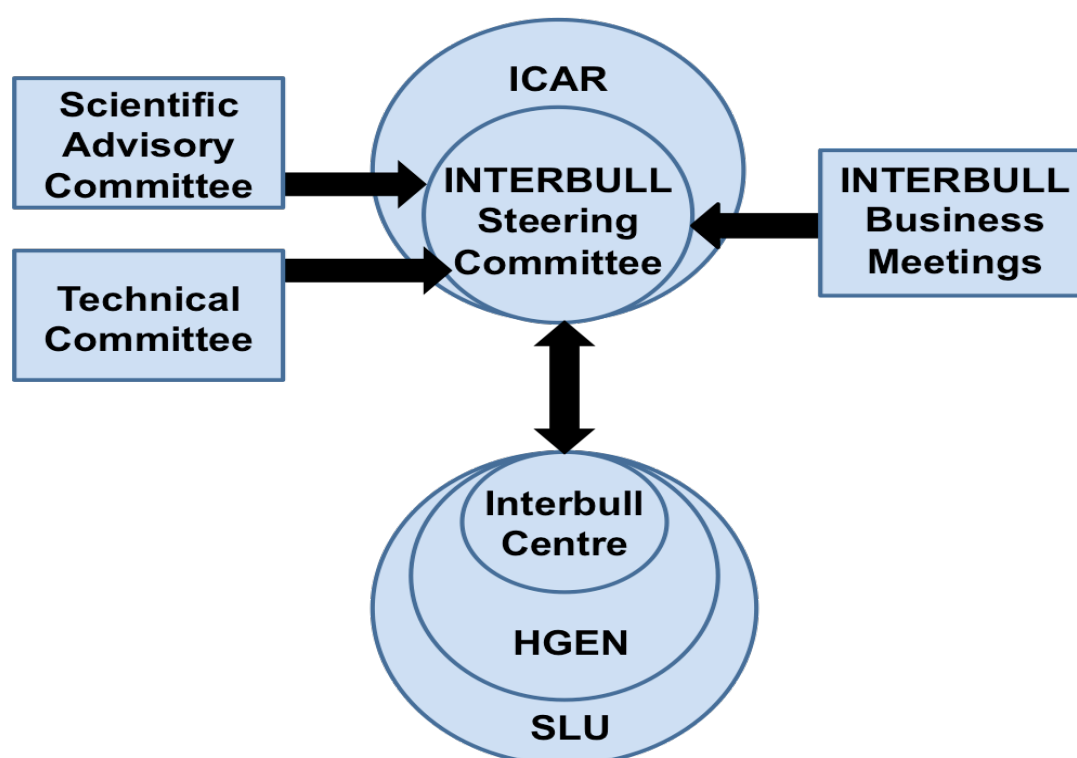


Figure 4.3: Organisational structure of Interbull

Current members of the Interbull Steering Committee:

- Reinhard Reents, PhD, Chairperson of IB-SC, VIT, Germany
- Gert Pedersen Aamand, PhD, Chairperson ITC, NAV, Denmark
- Gordon Doak, NAAB, USA
- Maria Klopčič, PhD, Associate professor, University of Ljubljana, Slovenia
- Sophie Mattalia, MSc, INRA-SGQA, France
- Enrico Santus, PhD, ANARB, Italy
- Matthew Shafer, PhD, DataGene, Australia
- Brian Van Doormaal, MSc, CDN, Canada
- Marco Winters, PhD, AHDB Dairy, Great Britain

Current members of the Scientific Advisory Committee:

- Vincent Ducrocq, PhD, senior scientist, Chairperson of SAC, INRA, France
- Daniel Gianola, PhD, Professor, University of Wisconsin, USA
- Mike Goddard, DVM, PhD, Professor, University of Melbourne, Australia
- Ignacy Misztal, PhD, Professor, University of Georgia, USA

Current members of the Interbull Technical Committee:

- Gert Pedersen Aamand, PhD, Chairperson of ITC, NAV, Denmark
- Gerben de Jong, PhD, CRV BV, The Netherlands
- Hossein Jorjani, DVM, PhD, Professor, SLU, Sweden
- Gerrit Kistemaker, PhD, CDN, Canada
- Tom Lawlor, PhD, Holstein USA, USA
- Zengting Liu, PhD, VIT, Germany
- Raphael Mrode, PhD, SRUC, Great Britain
- Esa Mäntysaari, PhD, professor, LUKE, Finland
- Peter Sullivan, PhD, CDN, Canada
- Paul VanRaden, PhD, USDA, USA

4.3.3. The Interbull Centre's Role as a Research Section within a University

As employees within a section of SLU's Department of Animal Breeding and Genetics, the Interbull Centre staff performs all duties relevant to university employees, e.g. teaching, advising undergraduate and postgraduate students, research and dissemination of scientific research results to the industry users and the general public. This also includes the Interbull Centre's administrative roles as described previously.

4.3.4. The Interbull Centre's Ultimate Role

Interbull is a worldwide network providing genetic information services for improvement of livestock.

The Interbull Centre facilitates international trade of cattle genetics, by:

- Neutral international assessment of genetic merit for dairy and beef traits and breeds
- Aiding in the exchange of genomic information and strategies/methodologies utilized in the genomic selection.
- Ensuring the quality control of the above by setting standards and implementing validation methods.

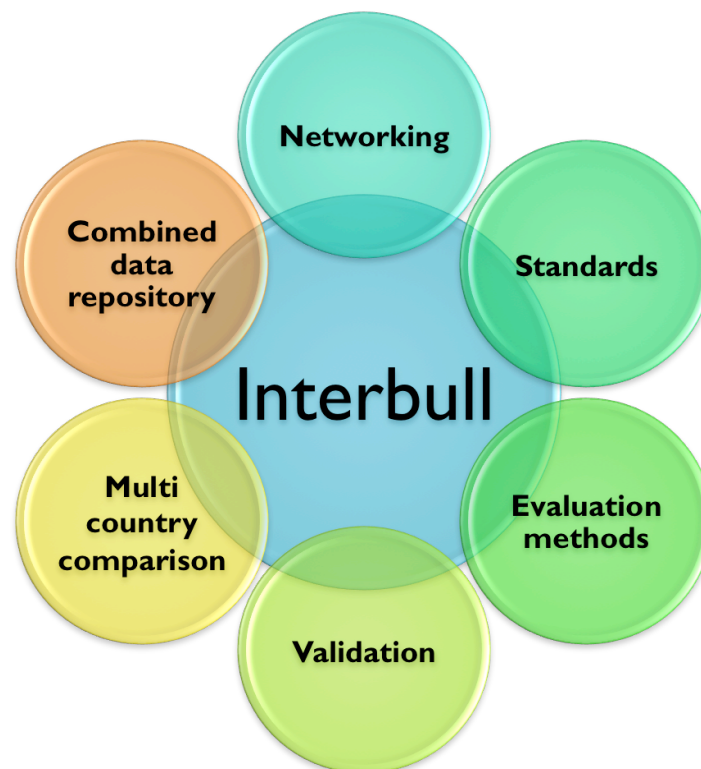


Figure 4.4: Interbull and Interbull Centre's role

5. Quality Management and ISO 9001 Certification

The Interbull Centre's quality management system for international genetic and genomic evaluations of dairy cattle ("*Interbull MACE*" and "*Interbull GMACE*") have been SS-EN ISO 9001:2008 certified since January 2016 (Certificate no. SE004561-1). In line with continuous improvement practices, our quality management system for international beef genetic evaluations ("*InterBeef*") has since also been certified. Upgrading to the new ISO 9001:2015 standard (which includes additional focus on management practises and risk management) is also in progress.

Verification and validation of data, handling of non-conformities, planning for improvements and customer satisfaction are integral parts of all services carried out at the Interbull Centre and are hence included in the above mentioned accredited management system.

The ISO 9001:2008 quality management standard was developed and published by the International Organization for Standardization (ISO). Important components of ISO 9001:2008 include customer satisfaction and establishing processes for continuous improvement.



Interbull Centre's ISO 9001 certification was obtained through the certification body Bureau Veritas. Created in 1828, Bureau Veritas is a global leader in Testing, Inspection and Certification (TIC), with offices in 140 countries.

The first surveillance audit by Bureau Veritas occurred in December 2016. Interbull Centre successfully passed the audit with a complete absence of non-conformities found.

The management standards help to increase the level of robustness of our systems and the already high quality of service offered to our customers. With independent certification of Interbull Centre by an outside auditor, more than ever the Interbull Centre can stand behind its quality policy of performing its services according to its Guiding Principles, as listed in the Interbull Centre's quality management manual.

Interbull Centre Guiding Principles

- Accurate predictions
- Independence
- Timely delivery
- Documented methods and practices publicly available
- Unbiased statistics
- Comprehensive communication

6. The Interbull Centre's Computing Infrastructure

The Interbull Centre has an efficient, effective, versatile, scalable, and powerful computing infrastructure. It consists of customer facing software services and databases for data exchange (IDEA, GenoEx), a cluster system with attached clustered file storage that is used for high-performance data analysis as well as tools for system monitoring, operational system management, backups, communication and project management. Software costs have

been reduced to a minimum by use of well-vetted open source components, the performance and ease of maintenance of the system has been honed by years of experience doing large-scale data analysis at the Interbull Centre. By continuous investment in infrastructure improvement the Interbull Centre has been able to provide an increased number of traits and services within strict deadlines, as exemplified in the tables with statistics on each of the services.

6.1. Hosting

Interbull Centre hosts its infrastructure in two main locations. Production level and crucially important servers are kept at the University's dedicated server hall. The second location is a temperature controlled, secure and access-controlled computer hall in close vicinity to the Interbull Centre's offices. This location serves partly as a hosting facility for the data analysis infrastructure that needs occasional hands-on maintenance and partly as a laboratory for developing the future infrastructure of the Interbull Centre. There is also a third, smaller, separate location, which holds additional backup infrastructure for redundancy.

6.2. Hardware

The hardware consists of server-grade computers running the customer-facing services and databases as well as various internal systems (monitoring, communication etc.). The data analysis system currently consists of server-grade computers for administrative purposes —



Figure 6.1: Signs inside VHC for the Interbull Centre, In Silico Lab and HGEN.

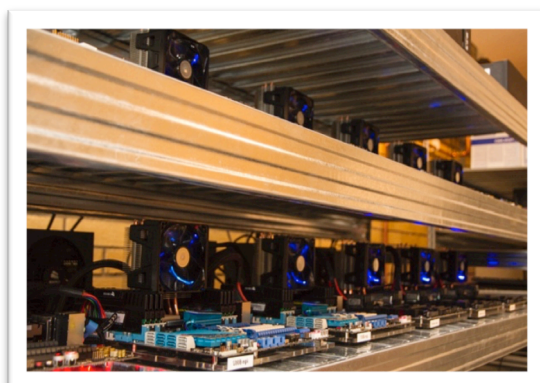


Figure 6.2: Equipment inside the In Silico Lab.

network boot, clustered file storages and entry point— as well as a number of cost-effective, powerful, customized units for data analysis. These computers are connected in a high-performance, secured network to ensure the integrity and the exclusive usage of the system, as well as easy maintenance.

In addition, a dedicated file server is used for warm backups of data while an additional server and a tape machine is used for cold, long-term storage of backups.

6.3. Software Architecture

Interbull Centre bases its operations on custom in-house developed software, well-vetted open source components and a few industry-leading software packages from third parties. Software is adopted or developed to enable Interbull Centre staff and customers (from the academia and industry) to work efficiently solving their tasks and activities. The system is built with security and data integrity in mind.

The in-house software (IDEA and various data analysis packages) is based on decades of improvements in providing international dairy breed evaluations. The data analysis system is easily scaled up when demand for more processing power increases. It is constantly developed and refined to become an even better environment for data analysis.

As mentioned, Interbull Centre relies on the vast ecosystem of open source software to solve many of its tasks and activities. By using well-known community developed software, costs are reduced and recruitment of trained staff is simplified. Meanwhile the staff can focus on customizing and developing solutions for the tasks that are specific for the Centre.

6.4. Information Security

Access to systems and data at the Interbull Centre is restricted. Customer facing systems are password protected and the network traffic is encrypted with HTTPS. Staff access to file storage and the data analysis system is through the encrypted secure shell protocol (SSH). Operational system management is also performed over SSH, but only by IT staff. Internally the systems (e.g. GenoEx and IDEA) connect to databases and sub-systems through encrypted connections (TLS, SSH).

Servers at the Interbull Centre run CentOS Linux (with a few specialized exceptions). Firewalls – with very restrictive settings – provide external security. To limit the risk and scope of intrusions the systems have the SELinux (Security Enhanced Linux) subsystem enabled for an extra layer of security.

The security aspects of the system are routinely discussed and improved. In addition, the system monitoring software detects problems and suspicious activity in an automated fashion.

To protect against information loss and reduced availability multiple layers of redundancy and backups are in place. Files are stored on a clustered file system, which keeps running even if a whole server becomes unresponsive or needs maintenance. In addition, file servers and database servers store their data redundantly on multiple hard disks using RAID. Databases, applications and file storage are backed up at regular intervals. The backups are

placed on a file server that acts as a warm backup. Copies of the data are then made to cold (tape) storage. The most important data is kept in backups indefinitely, while working data are kept for months or years depending on the type and size of the data. Backups are restored and examined as a routine part of operations.

6.5. Applications

6.5.1. GenoEx – International Genotype Exchange Platform

During recent years the infrastructure necessary for the International **Genotype Exchange** Platform, “GenoEx”, has been established at the Interbull Centre, with financial support from Interbull, SLU and ICAR. The GenoEx platform has been established in order to:

- a) establish the infrastructure necessary for international cooperation based on SNP data;
- b) optimise customer investments in genotyping by avoiding duplication
- c) establish standard protocols for genomic data exchange;
- d) become the international source of bovine parentage SNPs;
- e) facilitate multilateral SNP data exchange by establishing a common repository and customer driven access rules; and
- f) provide affordable genomic data storage for small populations.

Current and future services that will be provided through the GenoEx platform are differentiated into three categories:

- **Parentage SNP Exchange (GenoEx-PSE);**
- **Genotype Data Exchange (GenoEx-GDE);**
- **Customised Genotype Repository (GenoEx-CGR).**



The first of these, **GenoEx-PSE**, is a service for exchanging standardised sets of SNP for genotyped animals to facilitate parentage analysis activities. The service was launched during the joint ICAR-Interbull Meetings in Puerto Varas, Chile, in October 2016. The implementation took place under the guidance of the ICAR-appointed GenoEx-PSE Implementation Task Force, responsible for proposals of GenoEx-PSE policies and business rules, and the GenoEx-PSE Expert Group, addressing specific scientific and technical issues.

Bilateral exchanges may become inefficient and cumbersome if clear standards for data sharing are not established and multiple partners are involved. With **GenoEx-GDE** customers will be able to store and share their own marker genotypes with other customers through the GenoEx Platform. Users of **GenoEx-CGR** will be able to store and process their genomic information using exclusive partitions of the GenoEx database through remote access. In other words; national evaluation units will be able to outsource the database services to the Interbull Centre, while keeping exclusive access to their data.

GenoEx provides a much-needed international platform for genomic information exchange. As a cooperative effort that would involve only those customers interested in benefiting from the proposed platform, it does not prevent other Interbull customers to continue developing their own strategies and infrastructure. As it is the case for all Interbull activities, there is no intention to replace or compete with national organisations. On the contrary, GenoEx was conceived to offer auxiliary tools for the national expertise to develop their own programs more efficiently.

Reference:

- J. W. Dürr, H. Jorjani & R. Reents, Proc. ICAR/Interbull Conference, Berlin, Germany, May 19-23, 2014. 10 p.

6.5.2. IDEA (Interbull Data Exchange Area)

Interbull Data Exchange Area (IDEA) is the main web service run by the Interbull Centre and facilitates the collection of data from all clients and customers, as well as the distribution of data. It is an exclusive area just for the allowed participants, protected by user logins and HTTPS (secure web traffic). Through the web site the users can retrieve, update and add pedigree information, breeding values, phenotype data and additional animal information which are used for Interbull Centre's evaluations. The Interbull Centre service staff can similarly monitor and manage the data flow by using the administration level tools and functionality in the web site, and to verify and ensure that the data is sound and correct.

6.5.3. AnimInfo (Animal Information)

Through the AnimInfo module in IDEA it is possible to store any kind of information about the animals in the system. The data is uploaded in a uniform fashion, through a flexible and extendable file format, which can be altered by the Interbull Centre staff through the IDEA admin web interface. Currently the system is used for various data, such as genetic traits, crossbreeding information and indicating whether an animal has been genotyped or not. It is anticipated that the type and volume of information stored in AnimInfo will be expanded significantly.

7. The Interbull Centre's Activities

Interbull Centre's work in the past (22 years since the first official release of the results from an international genetic evaluation) has been commensurate with its tasks as a European Union Reference Centre, according to the EU Regulations on Animal Breeding that were valid at the time. Most of these tasks have a direct correspondence with the 8 Interbull Centre activities that are mentioned below. There are however tasks which – at first view - may not be directly associated with the Interbull Centre activities. One example is that the work at the Interbull Centre has had enormous harmonising effects on the choice of traits in different countries, and also the choice of trait definitions. This has been a direct effect of the estimated genetic correlations at the Interbull Centre. One example is the female fertility trait commonly known as “non-return rate = NRR”, i.e. the cow becoming pregnant after insemination and not returning for another insemination. During the research conducted at the Interbull Centre (2002-2006) several variants of NRR could be found in different countries (NRR28, NRR56, or NRR90, i.e. pregnancy examination after 28, 56, or 90 days, respectively). Nowadays, it is very common to only use the trait NRR56.

The proximity of the time that Interbull Centre was designated as EURL-Z (1996) after its first routine international evaluation (1995) has been instrumental in development of the Interbull Centre's strategy to focus on research and development activities that are of mutual benefit to the Interbull Centre's service users and to its role as EURL-Z. The most important of such activities are listed below:

- 1- Monitoring of the performance testing at different countries (dairy and beef);
- 2- Monitoring of genetic evaluations of different countries (dairy);
- 3- Validation tests of genetic and genomic evaluation of different countries (dairy);
- 4- Providing international genetic evaluation based on national genetic evaluations (dairy);
- 5- Providing international genetic evaluation based on national performance data (beef);
- 6- Providing international genomic evaluation based on national genomic evaluations (dairy);
- 7- Providing international genomic evaluation based on national genotypes (dairy);
- 8- Operating international database for pedigree, performance, genotype, and national genetic evaluation results.

7.1. Monitoring of the Performance Testing at Different Countries (Dairy and Beef)

The Interbull Centre continuously monitors the performance testing schemes and national genetic and genomic evaluation systems of its member countries. This is done through extensive standard questionnaires called GE, and GENO forms, each of which has an appendix with relevant numerical information.

The GE and GENO forms contain essential information about the details of the national system, such as the methods of trait measurements, the group of animals (especially sires), and statistical models. The appendix to each form contains the phenotypic and genetic means, variances, and covariances of the populations concerned.

7.2. Monitoring of Genetic Evaluations of Different Countries (Dairy)

The Interbull Centre is extensively monitoring genetic evaluations in all the countries participating in the international genetic and genomic evaluations through the use of the verify program. Data submitted by the users into IDEA (Interbull Data Exchange Area) are automatically checked by the Verify program. These checks include basic statistics, comparisons with previous evaluations, sire variances for the whole population but also for some specific sub-groups and individuals. The Methods used in the Verify program are described in Klei et al., 2002.

Interbull Centre staff uses the output of the Verify program to decide if the new data it has received is qualified to be included in the international evaluations. The output of the Verify program is also used by Interbull Centre users (i.e. the National Genetic Evaluations Centres), as it is a powerful tool to detect mistakes and issues in their national evaluations or data processing systems. Following a request from the users, the Interbull Centre provides a stand-alone version of the verify program that can be run outside IDEA for both national conventional and genomic data.

Table 7.1: Size of Interbull Centre operations for the Verify program.

DATA CHECKED BY THE VERIFY PROGRAM	Dec 2014	Dec 2015	Dec 2016
Number of countries	34	34	33
Number of evaluation breeds	6	6	6
Number of country-breed-trait combinations ¹	2159	2505	2151
Number of breed-trait evaluations	209	214	224
Number of submitted national estimated breeding values	23428752	28897744	31610582
Number of qualified national estimated breeding values	15909877	20483990	21355610

Reference:

- Klei et al., 2002. Interbull Bulletin 29:178-182.

7.3. Validation Tests of Genetic and Genomic Evaluation of Different Countries (Dairy)

The Interbull Centre applies four different genetic trend validation tests for monitoring of performance test based genetic evaluations and one validation test for monitoring of genomic based evaluations.

7.3.1. Validation Methods

A brief description of the four validation methods follows:

Validation Method I: Comparison of genetic trends estimated using only first lactation versus all lactations in the national genetic evaluations. The method aims at investigating the impact of cow records from different age groups on the genetic trend.

Validation Method II: Analysis of within bull yearly Daughter Yield Deviations. Daughter Yield Deviations are independent of the year of calving of bulls' daughters. This method investigates the non-genetic time trend over the entire period considered in the national evaluation.

Validation Method III: Analysis of official national predicted genetic merit variation across evaluation runs. The methods aims at investigate the random variation associated with new daughters.

The fourth validation test is called Mendelian sampling trend validation aiming at validate the consistency of Mendelian sampling variance in national evaluation models by estimating within-year genetic variances, fitting a weighted regression model on them, identifying possible outliers that do not fit the model and defining 95% empirical CI for a trend.

Monitoring of performance testing of genomic evaluations is done by the GEBV-test. The test evaluates two main aspects:

- 1) Unbiasedness of national genomic evaluations through evaluation of consistency of the genetic trend captured by GEBV and the consistency of the variation of GEBVs and EBVs;
- 2) Improvement in accuracy from the use of GEBV instead of EBV.

Table 7.2: Size of validation activities

SIZE OF VALIDATION ACTIVITY	Dec 2014	Dec 2015	Dec 2016
Number of validation tests for EBV	183	132	150
Number of validation tests for GEBV	186	139	158

7.3.2. Official GEBV-Test Rules

The official GEBV-test rules and test results are available on the Interbull Centre website, and are repeated below:

- The GEBV-test is needed whenever there is a major change either in the genomic evaluation or in the conventional evaluation. Additionally, if there is a major change in the reference population a new GEBV-test should be required. GEBV-test is valid for only two years.
- Following decision by the ICAR board, all countries that want to validate national GEBVs need to participate in the GEBV-test starting on April 12, 2012, for all production traits (milk, fat and protein yields).
- The expected regression coefficient for the GEBV-test model 1 should be within the confidence interval of plus minus two times the standard error (t test).
- For very large reference populations, however, the SE becomes too small and makes the above criteria too restrictive. Therefore, it is proposed a “biological confidence interval” of ± 0.1 .
- The R-square of model 1 should be higher than the R-Square of model 2.
- GEBV-test should only be noted as failed if regression coefficients are significantly lower than the expected value (=over evaluation of young bulls), or higher than 1.20.

Table 7.3: The following populations have succeeded to provide the information requested and passed the GEBV-test (Please note that some GEBV-test results are older than 2 years).

Population	Breed	Date of latest validation	mil	fat	pro	Organization providing data
AUS	HOL	201402	Y	Y	Y	Australian Dairy Herd Improvement Scheme (ADHIS)
AUS	JER	201302		Y	Y	Australian Dairy Herd Improvement Scheme (ADHIS)
BEL	HOL	201609	Y	Y	Y	Faculté Universitaire des Sciences Agronomiques - Groupe de Génétique et Amélioration Animales
CAN	BSW	201302	Y	Y	Y	Canadian Dairy Network (CDN)
CAN	HOL	201501	Y	Y	Y	Canadian Dairy Network (CDN)
CAN	JER	201302	Y	Y	Y	Canadian Dairy Network (CDN)
CAN	RDC	201302	Y	Y	Y	Canadian Dairy Network (CDN)
CHE	BSW	201608	Y	Y	Y	Qualitas AG
CHE	BSWi	201307	Y	Y	Y	Intergenomics
CHE	HOL	201608	Y	Y	Y	Qualitas AG
CHE	RHO	201302	Y	Y	Y	Qualitas AG
CZE	HOL	201509	Y	Y	Y	Czech Moravian Breeders' Corporation (PLEMDAT)
DEA	BSW	201601	Y	Y	Y	Bavarian State Research Center for Agriculture (LfL)
DEA	BSWi	201307	Y	Y	Y	Intergenomics
DEU	HOL	201609	Y	Y	Y	Vereinigte Informationssysteme Tierhaltung w.V (vit)
DEA	SIM	201601	Y	Y	Y	Bavarian State Research Center for Agriculture (LfL)
DFS	HOL	201609	Y	Y	Y	Nordic Genetic evaluation (NAV)
DFS	JER	201612	Y	Y	Y	Nordic Genetic evaluation (NAV)
DFS	RDC	201612	Y	Y	Y	Nordic Genetic evaluation (NAV)
ESP	HOL	201501	Y	Y	Y	Confederation of Spanish Holstein Associations (CONAFE)
FRA	BSWi	201307	Y	Y	Y	Intergenomics
FRA	HOL	201701	Y	Y	Y	France Génétique Elevage
FRA	MON	201501	Y	Y	Y	France Génétique Elevage
FRA	NMD	201501	Y	Y	Y	France Génétique Elevage
GBR	HOL	201507	Y	Y	Y	Scotland's Rural College (SRUC)
IRL	HOL	201108	Y	Y	Y	Irish Cattle Breeding Federation
ITA	BSWi	201307	Y	Y	Y	Intergenomics
ITA	HOL	201406	Y	Y	Y	Associazione Nazionale Allevatori Frisone Italiana (ANAFI)
ITA	SIM	201609	Y	Y	Y	Associazione Nazionale Allevatori Pezzata Rossa Italiana (ANAPRI)
JPN	HOL	201509	Y	Y	Y	National Livestock Breeding Centre
NLD	HOL	201612	Y	Y	Y	Genetic Evaluation Sires (GES)
NZL	HOL	201007			Y	Livestock Improvement Corporation
NZL	JER	201007			Y	Livestock Improvement Corporation
POL	HOL	201510	Y	Y	Y	Polish Federation of Cattle Breeders and Dairy Farmers
SVN	BSWi	201307	Y	Y	Y	Intergenomics
USA	BSW	201612	Y	Y	Y	Animal Improvement Programs Laboratory (AIPL-USDA)
USA	BSWi	201307	Y	Y	Y	Intergenomics
USA	HOL	201409	Y	Y	Y	Animal Improvement Programs Laboratory (AIPL-USDA)
USA	JER	201409	Y	Y	Y	Animal Improvement Programs Laboratory (AIPL-USDA)

The following peer-reviewed publications provide deeper insight into the scientific principles on which the trend validation tests are based:

- Boichard, D., Bonaiti, B., Barbat, A. and Mattalia, S. 1995. Three methods to validate the estimation of genetic trend for dairy cattle. *J. Dairy Sci.* 78, 431-437.
- Weller, J. I., Emanuelson, U. and Ephraim, E. 2003. Validation of genetic evaluation methodology using the nonparametric Bootstrap Method. *Interbull Bulletin* 31, 26-29.
- Lidauer, M., Mäntysaari, E.A., Pedersen, J. and Strandén. 2005. Model validation using individual daughter deviations – statistical power. *Interbull Bulletin* 33, 195-199.
- A.-M. Tyrisevå, et al., 2012. Validation of Consistency of Mendelian Sampling Variance in National Evaluation Models. *Interbull Bulletin* 46, p.97-102

- Mäntysaari, E., Liu, Z and VanRaden P. 2011. Interbull Validation Test for Genomic Evaluations. Interbull Bulletin 41, p. 17-21.

7.4. Providing international genetic evaluation based on national genetic evaluations (dairy)

Interbull uses a scientifically advanced method known as Multiple Across Country Evaluation (MACE) to calculate International Genetic Evaluations. MACE was first developed in 1994 by Professor Larry Schaeffer (International genetic evaluation computation: Schaeffer. 1994. J. Dairy Sci. 77:2671-2678) and subsequently modified by Klei (Solving MACE Equations, 1998. Interbull Bulletin 17:3-7).

MACE has two major advantages over other methods:

- 1- Use of all known relationships between animals: MACE combines information from each country using all known relationships between animals, both within and across populations;
- 2- Genotype by environment interactions: MACE accounts for the possibility of animals re-ranking between certain countries. This occurs when animals perform better in certain environments than they do in others or when genetic evaluation methods differ between countries. For this reason, a separate set of results is calculated for every participating country.

The detailed workflow is as follows:

1. **De-regression:** methodology to deprive national EBVs of their environmental and national pedigree effects. The methodology applied by Interbull Centre is in accordance with the study by Sigurdsson and G. Banos. 1995. *Acta Agric. Scand.* 45:207-219 and Jairath et al. 1998. *J. Dairy Sci.* Vol. 81:550-562
2. **Genetic parameter estimation:** to calculate correlations across countries for all traits and breeds is in accordance with the study by Klei and Weigel, 1998, *Interbull Bulletin* 17:8-14 and Sullivan, 1999. *Interbull Bulletin* 22:146-148
3. **Post-processing of estimated genetic correlations:** Genetic correlations are subjected to fluctuate across countries for reason not related to the genetic connectedness of the countries but more for environmental reasons like for example differences among countries with similar climate or production system (grazing vs. not grazing, for example). To remove such noise from the estimated correlation a procedure is applied based on the study by Mark et al., 2003, *Interbull Bulletin* 30:126-135 and Jorjani et al., 2003. *J. Dairy Sci.* 86:677-679 which allows estimates to fall within certain windows of minimum and maximum values.
4. **Time edits:** Weigel and Banos. 1997. *J. Dairy Sci.* 80:3425-3430
5. **International reliability estimation:** based on the study by Harris and Johnson. 1998. *Interbull Bulletin* 17:31-36

Interbull Centre dairy international genetic/genomic evaluations are carried out for six breeds (Holstein, Brown Swiss, Jersey, Ayrshire (including Red Dairy Cattle), Guernsey, Simmental); for seven trait groups comprising a total of 50 different traits; for a total of

thirty-two countries. International genetic evaluation for beef cattle includes evaluation for two (2) breeds (Charolais and Limousin), for one trait, adjusted weaning weight.

The trait groups considered for dairy evaluation are Production (milk, fat and protein yield), Conformation (nine traits related to the conformation of udder, nine traits related to general body condition and six traits related to locomotion), Udder Health (somatic cell score, mastitis), Longevity (direct longevity), Calving Traits (direct and maternal calving ease, direct and maternal stillbirth), Female Fertility (heifer fertility and four different traits related to cow's fertility) and Workability (milking speed, temperament).

Workability has been the latest trait group to be added to the Interbull Centre portfolio for progeny tested bulls, following a request from several NGCs wishing to have an international genetic/genomic evaluation for such traits. In December 2016, instead, the conformation trait group for Brown Swiss animals has been increased by an additional ten (10) new traits related to general body condition, following a request from the Brown Swiss World Association.

Table 7.4: Size of Interbull Centre operations for MACE.

Multiple Across Country Evaluation (MACE)	Dec 2014	Dec 2015	2016
Number of countries	34	34	33
Number of evaluation breeds	6	6	6
Number of country-breed-trait combinations ¹	1,833	2,166	2,184
Number of breed-trait evaluations	171	176	186
Number of animals in the pedigree database	23,084,236	24,981,462	27,896,152
Number of submitted national estimated breeding values	11,030,135	11,573,393	12,182,435
Number of qualified national estimated breeding values	6,086,142	6,348,587	6,504,328
Number of calculated international estimated breeding values	265,634,220	270,221,873	282,411,323
Number of distributed international estimated breeding values	102,965,388	103,108,350	109,765,575
Multiple Across Country Evaluation (MACE)	Sep 2014	Sep 2015	Sep 2016
Number of estimated across country genetic correlations ¹	13,168	12,548	13,088
Number of validation tests ²	183	132	150

¹ Merging of 2 populations in one country during 2015

² Subject to natural fluctuations

The MACE international genetic evaluations are based on the following scientific literature:

- Sigurdsson, A. and Banos. G. 1995. Acta Agriculturae Scandinavica. 45:207-219
- Jairath, L., Dekkers, J.C.M., Schaeffer, L.R., Liu, Z., Burnside, E.B., Kolstad, B.. 1998. Journal of Dairy Science Vol. 81:550-562
- Klei, L. and Weigel, K.A. 1998, Interbull Bulletin 17:8-14
- Sullivan, P. 1999. Interbull Bulletin 22:146-148
- Mark, T., Madsen, P., Jensen, J., Fikse, W.F. 2003, Interbull Bulletin 30:126-135
- Jorjani H., Klei, L., Emanuelson, U. 2003. Journal of Dairy Science 86:677-679

- Weigel, K.A., and Banos, G. 1997. Journal of Dairy Science 80:3425-3430
- Harris, B. and Johnson, D. 1998. Interbull Bulletin 17:31-36

7.5. Providing international genetic evaluation based on national performance data (beef)

In parallel with being the operational unit of the ICAR Permanent Sub-Committee Interbull, the Interbull Centre is also the operational unit for the ICAR Working Group Interbeef. In this respect, the Interbull Centre:

- Provides a forum for sharing knowledge on recording and genetic evaluations;
- Maintains guidelines and standards for beef cattle performance recording;
- Conducts international surveys relevant to beef cattle performance recording;
- Develops international genetic evaluation services, and
- Facilitates the use of genomic selection.

International genetic evaluation for beef cattle includes evaluation for two (2) breeds (Charolais and Limousin), for one trait, adjusted weaning weight.

Table 7.5: Size of the Interbull Operations for international evaluations of beef breeds Charolais and Limousin.

Interbeef	Jan 2015	Jan 2016
Number of countries	10	10
Number of evaluation breeds	2	2
Number of country-breed-trait combinations	18	18
Number of animals in the pedigree database	23,927,437	25,389,096
Number of submitted national estimated breeding values	7,210,100	7,472,166
Number of international estimated breeding values ¹	69,569,165	57,996,544
Number of distributed international estimated breeding values	938,179	1,108,658

¹ Change of rules during 2015

The beef international genetic evaluation is based on the following scientific literatures:

- Forabosco, F., V. Palucci, and J. W. Dürr. 2010. Guidelines to join Interbeef, version 2.1. Accessed Aug. 17, 2011. http://www-interbull.slu.se/Interbeef/General_info/Guideline_National_Plan_INTERBEEF_20110519_final.pdf. Interbull, Sweden.
- INRA. 2004. Final report. European beef evaluation. Accessed Aug. 17, 2011. http://www-interbull.slu.se/Beef_Gen_Ev/INRA_Final_Report_14_09_2004.pdf. Interbull, Sweden.
- Phocas, F., and K. Donoghue. 2004. Final report international evaluation research. Genetic Evaluation of Weaning Weight in France and Australia. Accessed Aug. 17, 2011. http://www-interbull.slu.se/Beef_Gen_Ev/AGBU_Final_Report_14_09_2004.pdf. Interbull, Sweden.
- Schild, H. J., B. W. Wickham, and H. Wilmink. 2005. Business plan for the implementation of international genetic evaluation services for beef breeds and traits by Interbull. Accessed Aug. 17, 2011. http://www-interbull.slu.se/Beef_Gen_Ev/Task_Force_Report.pdf. Interbull, Sweden.
- Sullivan, P. G. 2002. Genetic Evaluation Strategies for Multiple Traits and Client. PhD Thesis. University of Guelph, Canada.

- Phocas et.al. 2005. Investigation of three strategies of an international genetic evaluation of beef cattle weaning weight. GSE37 (4:361-380).

7.6. Providing international genomic evaluation based on national genomic evaluations (dairy)

This activity is based on an outgrowth extension expansion evolution of the MACE method mentioned in section 7.4, and is commonly known as Genomic Multiple Across Country Evaluation (GMACE). The idea behind this method (explained in the next paragraph) started to develop from the discussions of the members of Interbull Task Force (Banos et al, 2009). Then, two members of the Task Force (also members of ITC: VanRaden and Sullivan, 2010) followed the discussions and presented the suggestion. Later, Dr Sullivan continued the work on this subject under contract (outsourcing) by the Interbull Centre. This is an excellent example of international cooperation, and also an example of building a new system on the fly as the response to an emerging issue (i.e. start of the genotyping activities in member countries).

The GMACE method combines the results of the national genetic evaluations from countries with and without genomic evaluation, thus preserving the information from an established system (conventional genetic evaluations), and adding the information from the new genomic evaluations.

Table 7.6: Number of traits and the number of countries submitting GEBVs in the April 2016 GMACE routine run, per trait group. The breed is Holstein.

PROD (3)	CONF (21)	UDER (2)	LONG (1)	CALV (4)	FERT (5)	WORK (2)
11	11	10	8	7	9	6

Table 7.7: Size of the Interbull Centre operations for GMACE.

Genomic Multiple Across Country Evaluation (GMACE): Number of:	Dec 2014	Dec 2015	Dec 2016
Countries	34	34	33
Evaluated breeds	1	1	1
Country-breed-trait combinations	326	339	331
Breed-trait evaluations	38	38	38
Animals in the pedigree database	23,084,236	24,981,462	27,896,152
Submitted national estimated breeding values	12,398,617	17,324,351	19,428,147
Qualified national estimated breeding values	9,823,735	14,135,403	14,851,282
Calculated international estimated breeding values	129,211,446	153,062,674	155,263,850
Distributed international estimated breeding values ¹	7,468,896	7,000,306	11,700,382

¹ Change of publication rules during 2015 and 2016

The dairy genomic international evaluation is carried out by Interbull Centre by applying the **GMACE** methodology which is based on the following scientific literatures:

- VanRaden, P.M. and Sullivan, P.G. 2010. International genomic evaluation methods for dairy cattle. Gen. Sel. Evol. 42:7
- Sullivan, P.G. and Jakobsen, J.H. 2012. Robust GMACE for young bulls – methodology. Interbull Bulletin 45, Article 1.

- Sullivan, P.G. 2012a. GMACE reliability approximation. Report to the GMACE working group of Interbull. GMACE_rels 2013
- Sullivan, P.G. 2012b. GMACE variance estimation. Report to the GMACE working group of Interbull. GMACE_vce 2013
- Sullivan, P.G. 2012c. GMACE Weighting Factors. Report to the GMACE working group of Interbull. GMACE_gedcs 2013
- Jakobsen, J.H. and Sullivan, P.G. 2013. Trait specific computation of shared reference population. Reference sharing Nov 2013

7.7. Providing international genomic evaluation based on national genotypes (dairy)

Interbull Scientific Advisory Committee in its 2007 report envisaged three models for international use of Single Nucleotide Polymorphism (SNP) data (http://interbull.org/web/static/images_ibc/stories/SAC/sacreport2007.pdf). The simplest model was the use of results of national genomic evaluations based on SNP data. This is the GMACE activity mentioned above. The next model, with a higher degree of complexity, was to create a common reference population based on the SNP genotype of bulls from different countries. The objective of this model was to improve the prediction ability of the genomic equations which is particularly important for minor breeds by creating an international shared genotype database for cattle at the Interbull Centre, based on the fact that genomic predictions are highly dependent on the size of the reference populations.

Starting from 2009, the countries with Brown Swiss dairy cattle populations, requested implementation of such a model at the Interbull Centre. This activity gradually became known as the "Intergenomics". The Brown Swiss breed was (and still is) an ideally sized breed for the implementation of such model, because it is relatively small populations (with about 10,000 active bulls in the pre-genomic era), and the population is relatively equally spread in several countries. The SNP data sharing started already in 2009, and as soon as the number of genotyped animals reached a level that allowed validation of the genomic evaluation model, the official service started in 2011. This is a key project to enable Interbull Centre to continue providing guidance and cutting-edge methodologies to access genetic value of breeding livestock.

There has been a clear evolution on the concept of sharing genotypes internationally, and most countries recognize now the need of a common repository of bovine genotypes at the Interbull Centre as the means to:

- Reduce costs and optimize investments on genotyping bovine animals;
- Improve reference populations for prediction of genomically enhanced genetic merit, especially for low heritability health and functional traits, such as somatic cell count, mastitis, calving difficulty, longevity and female fertility;
- Make it possible to screen large populations for recessive alleles detection;
- Maintain a worldwide parentage verification data base, using the SNP based methods that are about to be officially recommended by ISAG and ICAR;
- Use the genomic data to study diversity within the bovine populations in a more complete way than is possible with the methods based on pedigree information only.

Table 7.8: Size of the Interbull Centre operations for InterGenomics.

InterGenomics (Genomic evaluation of BSW populations)	Dec 2014	Dec 2015	Dec 2016
Number of countries	8	8	8
Number of country-trait combinations	212	219	277
Number of unique submitted genotypes	16,599	20,561	26,794
Number of genotypes entering imputation & genomic evaluation	15,808	19,500	24,352
Number of distributed international GEBVs	N.A.	4,202,064	6,770,134

References:

- Loberg, A., Dür, J.W. & Jorjani, H. 2009. Genomic conversion equations. Interbull Bulletin 40: 151-154
- Jorjani, H. 2009. A general genomic simulation program. Interbull Bulletin 40: 202-206
- Banos G., Calus M., Ducrocq V., Dür J., Jorjani H., Liu Z., Mäntysaari E., Sullivan P., VanRaden P. 2009. Preliminary report from Interbull Task Force on the role of genomic information in genetic evaluations. Interbull Bulletin 39: 61-65
- Jorjani, H., B. Zumbach, J. Dür, E. Santus. 2011. Joint genomic evaluation of BSW populations. Interbull Bulletin 41: 8-13.
- Zumbach, B., H Jorjani & J Dür. 2011. Brown Swiss genomic evaluation. Interbull Bulletin 42: 44-51.
- Jorjani, H., J. Jakobsen, M.A. Nilforooshan, E. Hjerpe, B. Zumbach, V. Palucci & J. Dür. 2012. Genomic Evaluation of BSW Populations. InterGenomics: Results and Deliverables. Interbull Bulletin 43: 5-8.
- Loberg, A., H Jorjani & J. Dür. 2011. Validation of genomic national evaluations Interbull Bulletin 44: 62-66.
- Jorjani, H., J. Jakobsen, E. Hjerpe, V. Palucci & J. Dür. 2012. Status of Genomic Evaluation in the Brown Swiss Populations. Interbull Bulletin 46: 46-54.

7.8. Operating international database for pedigree, performance, genotype, and national genetic evaluation results

The Interbull Centre uses Pedigree and performance database (IDEA), a database for extra animal information such as genetic traits and defects (AnimInfo), and genotype database (GenoEx). These have been described in Chapter 6 (The Interbull Centre's Computing Infrastructure) under Section 6.5 (Applications).

8. International Scope

8.1. HGEN cooperation with international organisations

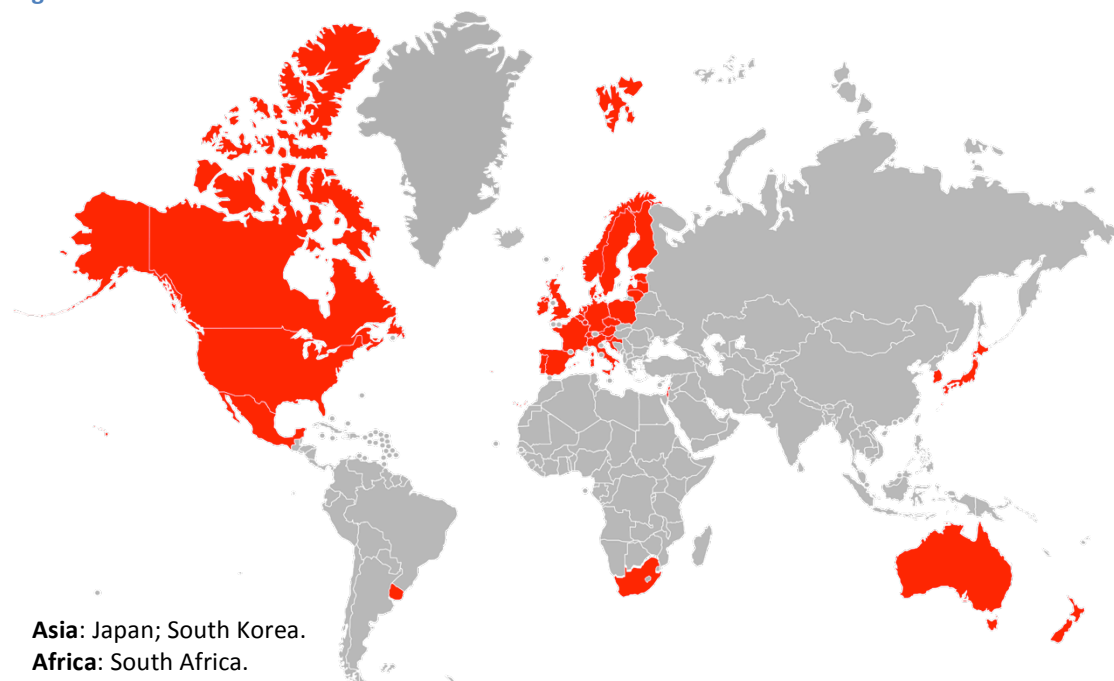
SLU, HGEN and the Interbull Centre are active in international networks and organisations. SLU, represented by Prof. DJ de Koning, is a member of the *European Sustainable Farm Animal Breeding and Reproduction - Technology Platform* ("FABRE-TP"), an industry-led forum which provides a framework for stakeholders to define research priorities and action plans for the farm animal and reproduction sector in order to achieve EU growth, competitiveness and sustainability through major research and technological advances in the medium and long term. The members of FABRE-TP consist of breeding and reproduction organisations and knowledge institutes.

Prof Rydhmer is a member of the council of the *European Federation of Animal Science* ("EAAP"), while Prof Strandberg is the President of EAAP's Commission on Animal Genetics.

8.2. Interbull's Global Reach

The Interbull Centre is the operational unit of Interbull. As such, the Interbull Centre is a very active player in the global "Interbull Community". The Interbull Centre provides international genetic evaluation service for dairy and beef cattle in 35 countries from 5 continents; Europe: 26 countries; America's: 4; Oceania and Asia 2 each; Africa: 1.

Figure 8.1: Interbull's Global Reach



Asia: Japan; South Korea.

Africa: South Africa.

America's: Canada; Mexico; Uruguay, USA

Europe: Austria; Belgium; Croatia; Czech Republic; Denmark; Estonia; Finland; France; Germany; United Kingdom; Hungary; Ireland; Israel; Italy; Latvia; Lithuania; Luxembourg, The Netherlands; Norway; Poland; Portugal; Slovak Republic; Slovenia; Spain; Sweden; Switzerland.

Oceania: Australia; New Zealand.

8.3. The ICAR Community

The International Bull Evaluation (“Interbull”) is a permanent sub-committee of the International Committee for Animal Recording (ICAR). As such there is already a close relationship between the Interbull Centre and ICAR. This relationship is ratified through an agreement that has been in place since 1995 to establish the Interbull Centre at SLU.



This relationship does not only provide the Interbull Centre direct, strong links with the Interbull Steering Committee. It also connects the Interbull Centre to the larger ICAR community.

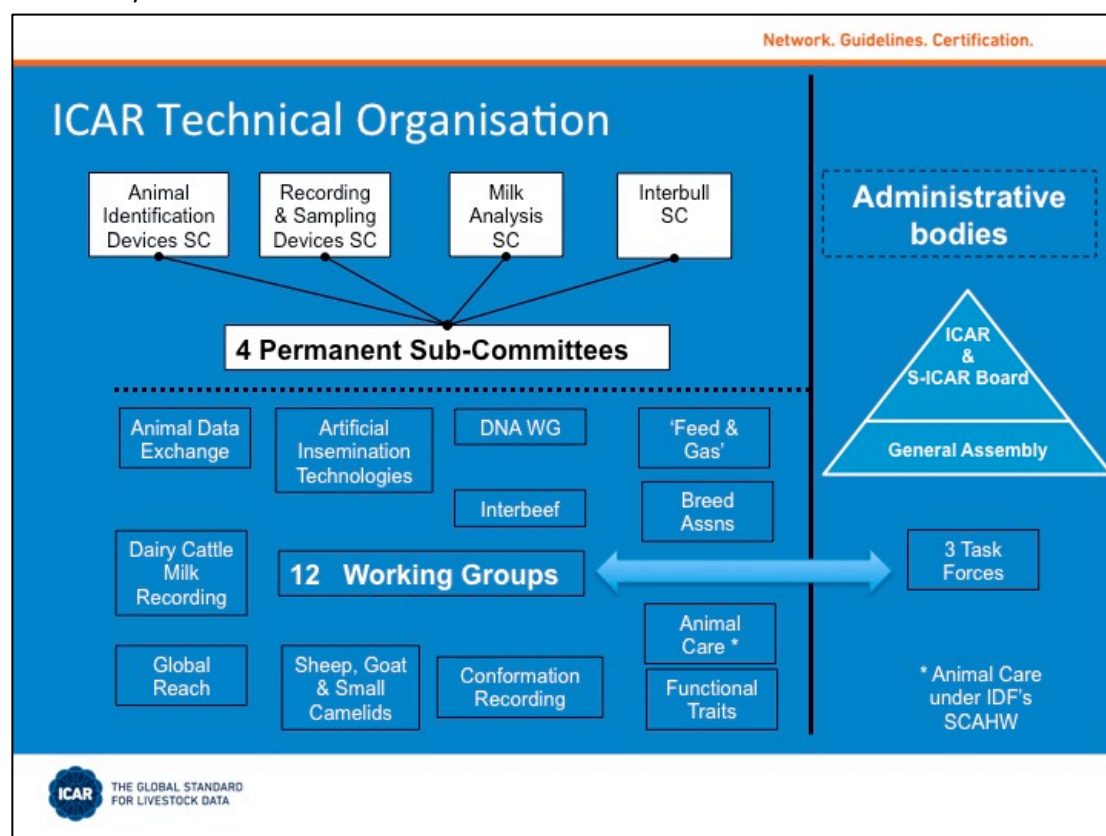


Figure 8.2: ICAR Technical Organisation

As is evident from the ICAR diagrams of the “Technical Organisation” and its “Permanent Building Blocks”, ICAR’s activities drive towards ensuring that genetic evaluation has access to the right kind of information from an animal with certain identity. This can be seen from the “Permanent subcommittees” that are pushing the data flow towards genetic evaluation. Also Working Groups and Task Forces work towards collecting quality ensured data and directing the data flow towards genetic evaluation.

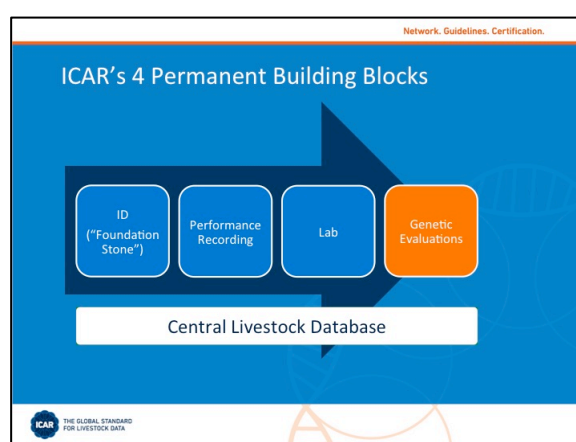


Figure 8.3: ICAR’s 4 Permanent Building Blocks

8.3.1. Interbeef

Although Interbull Centre members of staff are not official members of the ICAR Working Group “Interbeef”, staff does attend the meetings of this ICAR Working Group. Interbeef members are also invited to attend the Interbull Annual Meetings, and (one or more) themes for the Interbull Open Meetings are relevant to Interbeef members.

Current members of the ICAR Working Group “Interbeef”;

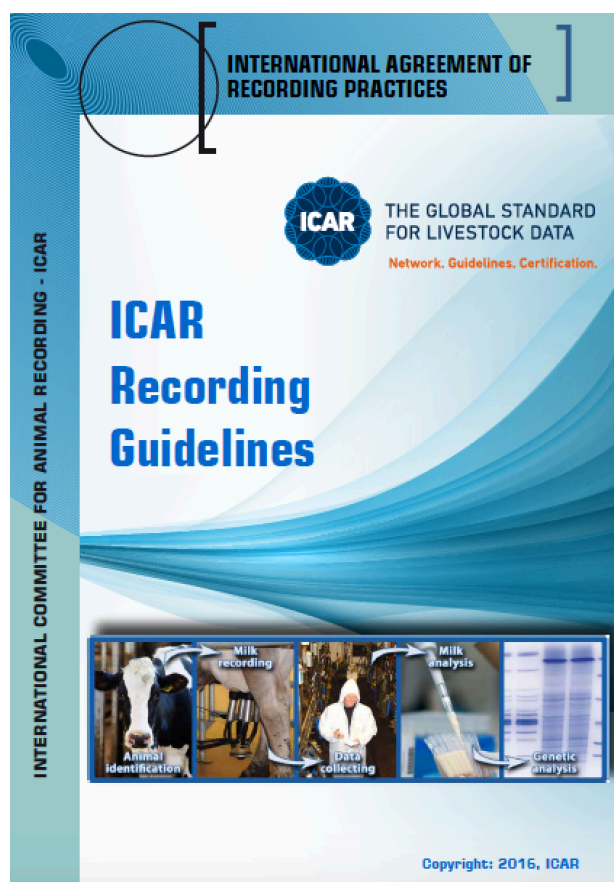
- Andrew Cromie, Irish Cattle Breeding Federation (Ireland)
- Robert Banks, Animal Genetics and Breeding Unit (AGBU), UNE (Australia)
- Pavel Bucek, Czech Moravian Breeder’s Corporation Inc., (Czech Rep.)
- Kirsty Moore, EGENES / SRUC, (United Kingdom)
- Clara Diaz, INIA, (Spain)
- Mauro Fioretti, Associazione Italiana Allevatori, (Italy)
- Anders Fogh, Knowledge Centre for Agriculture, (Denmark)
- Laurent Griffon, Institut de l’Elevage, (France)
- Friedrich Reinhardt (IT Solutions for Animal Production, w.V.), Germany
- Japie Van der Westhuizen, SA Stud Book and Animal Improvement Association, (South Africa)



8.3.2. ICAR Guidelines

ICAR Guidelines are publicly available. In order to support its members ICAR's guidelines are organized into sections that correspond with the animal recording operations of its members. ICAR guidelines are however also used by non-members, and referenced in legislation - such as in the EU Animal Breeding Regulation (Regulation (EU) 2016/1012).

The ICAR Guidelines will undergo a major update during 2017. The development and maintenance of the guidelines involves a group of experts in the field covered by each section, working collaboratively to determine best practice, to consult with other interests and to provide the required documentation. Interbull Centre staff will be leading the activities in relation to the chapters on Genetics and Genomics, and Animal Breeding.



8.4. Organisations of meetings, workshops and training activities.

One of the tasks assigned to the Interbull Centre by the “Terms of Reference and Rules of Procedure of Interbull Sub-Committee” (www.interbull.org/ib/termsofreference) is to:

- a) convene, prepare and organize Interbull Business Meetings;
- b) convene, prepare and organize Interbull Open Meetings;
- c) arrange seminars for exchange of scientific information and practical experiences in the field of national and international genetic evaluation of bulls and also on implications for cow evaluation;
- d) arrange workshops to facilitate the development of appropriate procedure for the international genetic evaluation.

8.4.1. Interbull Annual Meetings – an International Affair

We organise every year the Interbull Annual Meeting, which is internationally known as the leading event for research and development in bovine genetic and genomic national and international evaluations. We co-organise these annual meetings with internationally renowned organisations: jointly with the bi-annual conference of ICAR (International Committee for Animal Recording) in even years (2016, 2018, 2020, etc.), while alternating the odd years between EAAP (European Association for Animal Production; 2017, 2021, etc.) and ADSA (American Dairy Science Association; 2015, 2019, etc.). This has resulted in the following schedule, locations and co-organisers of recent and future Interbull Annual Meetings:

- 2013: Nantes, France (EAAP)
- 2014: Berlin, Germany (ICAR)
- 2015: Orlando, USA (ADSA and ASAS)
- 2016: Puerto Varas, Chile (ICAR)
- 2017: Tallinn, Estonia (EAAP)
- 2018: Auckland, New Zealand (ICAR and WCGALP)
- 2019: Cincinnati, Ohio, USA (ADSA)
- 2020: Leeuwarden, The Netherlands (ICAR)
- 2021: Davos, Switzerland (EAAP).

In 2015, the meeting was also organised with the American Society of Animal Sciences, while in 2018 the meeting will also be co-organised with WCGALP (World Congress in Genetic Applied to Livestock Production). Interbull organises joint sessions with EAAP and WCGALP at their respective meetings, even in the years that the Interbull Annual Meeting is not co-organised with these meetings.

8.4.2. Interbull Technical Workshops

The Interbull Centre generally organises two technical workshops over the course of three years. In 2015 and 2017 Interbull Centre has organized two technical workshops and one Industry meeting:

- Interbull Technical Workshop and Industry Meeting, February 2015, Verden, Germany
- Interbull Technical Workshop, February 2017, Ljubljana, Slovenia.

2015 Interbull Industry Meeting

Aim of the Industry meeting was to exchange information on the following subjects:

- Industry take up national (GEBV) and international (GMACE) genomic evaluations
- International Genotype Exchange Platform (GenoEx), Parentage SNP Exchange (PSE)
- Use of new data on genetic effects in breeding programs

2015 Interbull Technical Workshop

Aim of the workshop was to exchange knowledge on the following subjects:

- National experience with GMACE
- Progress report of genomic reliability task force
- International genetic correlations
- Pre-selection bias.

2017 Interbull Technical Workshop

In order to provide a good opportunity for the smaller countries in Central Europe to get involved with the application of genomic evaluation, we organised the 2017 Interbull Workshop in Ljubljana, Slovenia. Amongst the 70 participants (with representation from all continents) were indeed many from Central Europe, who all got involved in discussions on:

- how the international genetic evaluation methodology 'MACE' could handle the genomic information from 'single step' genomic evaluations and also how countries should deal with MACE when they are using 'single step';
- how conventional validation methods could be adapted in order to deal with effects introduced by genomic selection.



Figure 8.3: Activities during the 2017 Interbull Workshop.

For the development of a potentially new Interbull service, a possible Interbull pilot project on international meta-analysis of SNP effects was presented. Through international collaboration participating countries could estimate more accurate SNP effects and

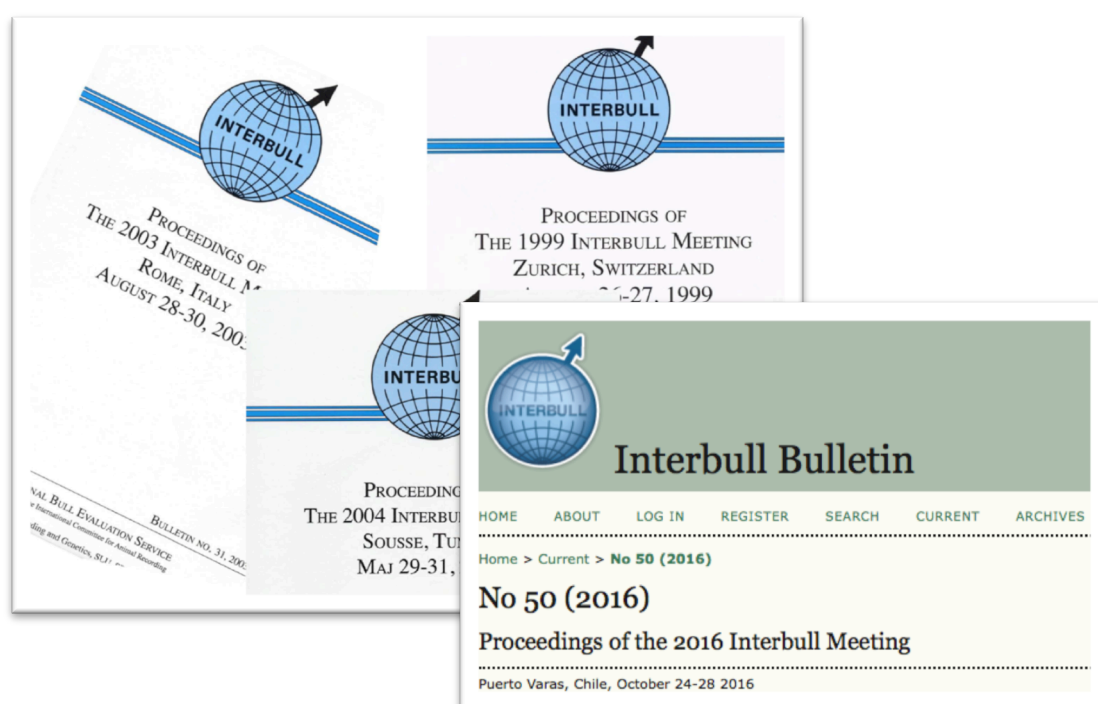
therefore more accurate genomic EBVs. In order to implement such new service, an idea on how to make optimal use of the Interbull Community's knowledge and expertise was presented.

8.5. Interbull Bulletin

Prof. Jorjani is the editor-in-chief for the Interbull Bulletin, which has been publishing results of Interbull meetings since 1986. The 50th issue was published in 2016.

The Interbull Bulletin has become a well-known reference for genetic evaluation of bovine cattle worldwide. It contains the state-of-the-art in genetic evaluation methods, as well as the most recent information on national and international implementations. Authors have an ideal forum to discuss new ideas and to challenge current genetic models. Following the Interbull Bulletin over the years presents a rich opportunity to understand how the current models were developed and how new traits were incorporated into genetic evaluations, and also provides information on Interbull's international standardisation activities. Interbull Bulletin Issue no. 28 in specific is dedicated to the Interbull Guidelines for national and international genetic evaluation systems in dairy cattle. These guidelines were then used for inclusion in the ICAR Guidelines.

Since 2011 the Interbull Bulletin is published online only. Back issues are also available online: <https://journal.interbull.org>.



8.6. International R&D Activities

Interbull is a worldwide network, which congregates most important breeding populations and genetic evaluation expertise worldwide. The scientific publications referred to in Chapter 7 of the current document are a testimony to the international cooperation of current and previous Interbull Centre staff with scientists from many countries. Many of

these publications are related to the improvement of the Interbull and Interbeef services provided through the Interbull Centre.

Such international research and development projects are also now in progress. Interbull Centre members of staff continue to be involved alongside appointed members of the Interbull Technical Committee/Steering Committee/Scientific Advisory Committee for dairy genetic and genomic evaluations and the Interbeef Working Group for beef evaluations. Current projects are:

1) **Further developments for InterGenomics**

- a) Implementation and validation of a quality protocol for national computations on InterGenomics genotype pools in order to assure the overall quality of the computations done at national level.
- b) Expansion of the service to different breeds than BSW. So far fifteen countries have shown interest in expanding InterGenomics service to the Holstein breed.

2) **Mendelian Sampling Trend Validation**

Development of a new trend validation test that could detect possible trends in genetic variances at national level. Under- or overestimation - of genetic variance in some country affects the spread of breeding values on other country scales, which can significantly affect the ranking of top bulls. National evaluation centres and Interbull therefore need a validation method to detect all significant trends that impede reliable ranking of bulls in the international sire evaluation.

3) **MACE robust to bias – ‘Robust MACE’**

Studying the impact on international breeding values of using a MACE model robust to bias in trends of national genetic evaluations.

4) **Genomic reliability calculation method:**

Defining standardized and simple methods/software to calculate national genomic reliabilities that can fit all possible situations encountered and lead to a better harmonization between countries.

5) **“SNP Mace”**

The Interbull Steering Committee and Technical Committee, the Interbull Centre and InterGenomics Management Committee are currently working on implementing a feasibility study on the ‘SNPMace’ model, as proposed by SAC member Michael Goddard. SNPMace potentially provides a good way to integrate foreign information into national genomic models. As such SNPMace could in the long term become part of the Interbull Centre’s service portfolio. Further preparations to implement this feasibility study with the use of Brown Swiss data are taking place.

8.7. Externally Funded Research

A number of externally funded research topics has been provided in section 3.4 “Research at HGEN”. More recently, HGEN and Interbull Centre have been approached by a number of consortia to be involved in their international projects. Central to the reason for these invitations are HGEN’s highly regarded scientific capabilities in the field of animal breeding and genetics, and Interbull Centre’s capacities and expertise as an International Central Data Hub, enabling International exchange of data and Quality Control. Also its status as the EU Reference Body for Bovine Breeding is an important factor.

Although Interbull Centre staff may also be carry out research activities, Interbull Centre is primarily expected to ensure the legacy of the projects by ensuring that the project results will be implemented beyond duration of the project. The Interbull Centre's role in standardising these results through the implementation of new guidelines and services facilitates subsequent implementation of such these results in additional countries and populations. The Interbull Centre's focus is hence on providing services to the project, ensuring quality control (verification and validation), and on developing services to the Interbull Community (several of whom are involved in the projects), as identified in the "Summary of Interbull Strategic Plan 2016-2018" (www.interbull.org/ib/ibc_strategic_plan). Two of these projects were approved for funding in 2017: GenTORE and ReDiverse.

GenTORE

Project title: "***Genomic management tools to optimise resilience and efficiency***"

Project Duration: 60 Months

Start date: 1 June 2017

Funding source: European Commission; Horizon2020, Research and Innovation action

EU project no.: 727213

Consortium composition: 13 partners from 8 EU and EAA countries.

The objective of GenTORE is to develop innovative genome-enabled selection and management tools to optimise cattle resilience and efficiency in widely varying environments. These tools, incorporating both genetic and non-genetic variables, will be applicable across the full range of systems (beef, milk and dual purpose), and will thereby increase the economic, environmental and social sustainability of European cattle meat and milk production systems.

ReDiverse

Project title: "***Biodiversity within and between European Red dairy breeds - conservation through utilization***".

Project Duration: 36 Months

Start date: 1 September 2017

Funding source: European Commission; Era-Net SUSAN

Project identifier: "ID 29"

Consortium composition: 21 partners from 10 EU countries and Switzerland.

Objectives:

- To conserve and utilize the unique biodiversity of European Red dairy breeds via improved genetic management together with acceleration of genetic gains for key dairy traits;
- To develop and to set in place collaborative and integrated novel breeding and management concepts to achieve a resilient and competitive use of these resources;
- To strengthen best practices for small farm holders for improving product quality and to supply ecosystem services according to their specific circumstances.

List of Abbreviations

ADSA	American Dairy Science Association
ASAS	American Society of Animal Science
EAAP	European Federation of Animal Science
EURL-Z	European Union's Reference Body for Zootechnics (Bovine Breeding)
FAO	Food and Agriculture Organization of the United Nations
GenoEx	International Genotype Exchange Platform
GMACE	Genomic Multiple Across Country Evaluation
HGEN	Department of Animal Breeding and Genetics at SLU
ICAR	International Committee for Animal Recording
IDEA	Interbull Data Exchange Area
IDF	International Dairy Federation
ITBC	Interbull Centre
ITC	Interbull Technical Committee
MACE	Multiple Across Country Evaluation
SLU	Swedish University of Agricultural Sciences
VHC	SLU's Centre for Veterinary Medicine and Animal Science at Campus Ultuna
WCGALP	World Congress in Genetic Applied to Livestock Production



INTERBULL CENTRE

**Department of Animal Breeding and Genetics
Swedish University of Agricultural Sciences - SLU**

Ulls väg 26, Box 7023, 750 07 Uppsala, Sweden

Phone: +46(0)18-67 2098

www.interbull.org

