ENABLED

THE RIO TINTO SPORTS INNOVATION CHALLENGE STORY

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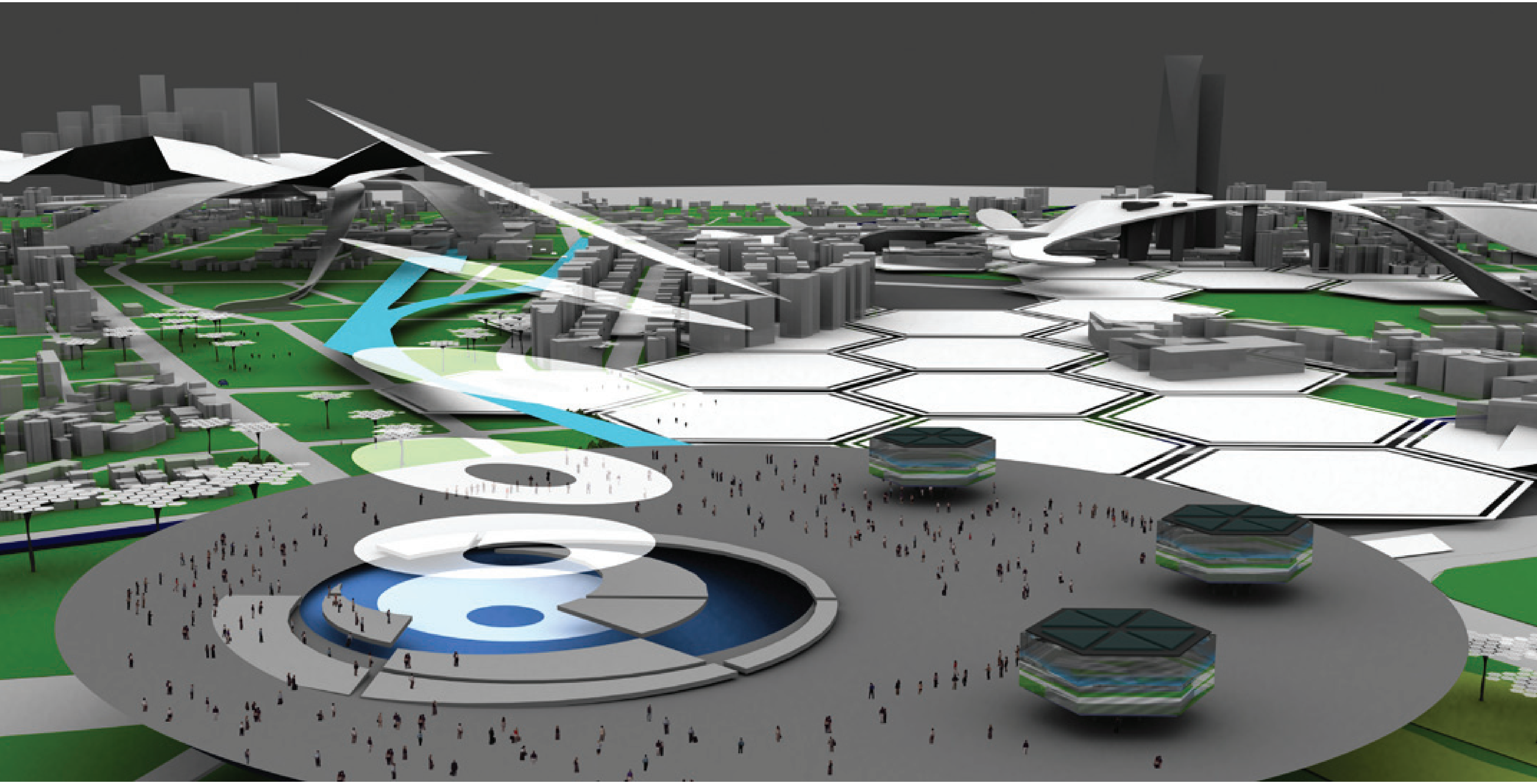
Enabled: The Rio Tinto Sports Innovation Challenge Story



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PREFACE

PETER CHILDS

Design can have an influence far beyond the initial activity on a product, process or system. Design represents a dynamic entity as a result of the interactions with the user and the context. Once released, a design can be adopted for uses, not initially considered, sometimes with unintended consequences. The world of design is used to the reach of the domain, and it is within this context that the Rio Tinto Sports Innovation Challenge was initiated.
The intention was to explore Paralympic sports, to see what design could offer. A wide open brief was developed and we pressed go. This book presents the contributions of the many participants, students, elite sportsmen and women, domain experts and course staff.

Peter Childs   March 2012

INTRODUCTION

PETER CHILDS

The Paralympian Oscar Pistorius, who, amongst many others, has made use of carbon fibre sprint feet, has provided inspiration to a new generation of people.
Another role model, Aimee Mullens, who was born without fibulae in both legs and later had her legs amputated from the knee, has promoted the idea of being ‘fashion-able’ referring to

‘how her legs give her super-powers’ through her repertoire of sprint, couture and glass legs. Aimee states: ‘[Disability] is no longer a conversation about overcoming deficiency. It’s a conversation about augmentation. It’s a conversation about potential...’

The Rio Tinto Sports Innovation Challenge was an intensive four week full-time course aiming to inspire students to propose new sporting opportunities ranging from Paralympic equipment through to radical new sporting events and competition models to facilitate active lifestyles for people with disability. The course was taken by students on the Innovation Design Engineering (IDE) degree programme, a two year full-time double masters, run jointly by Imperial College London and the Royal College of Art.
Many Olympic events date back to those based on a 2800 year old model, this was their opportunity to use technology, innovation and smart thinking to propose whole new game changing ideas focussed though Paralympic activity. Sport is not just about the competitor, but about the audience and amongst other challenges the students were asked to consider new engagement models for sports viewers.

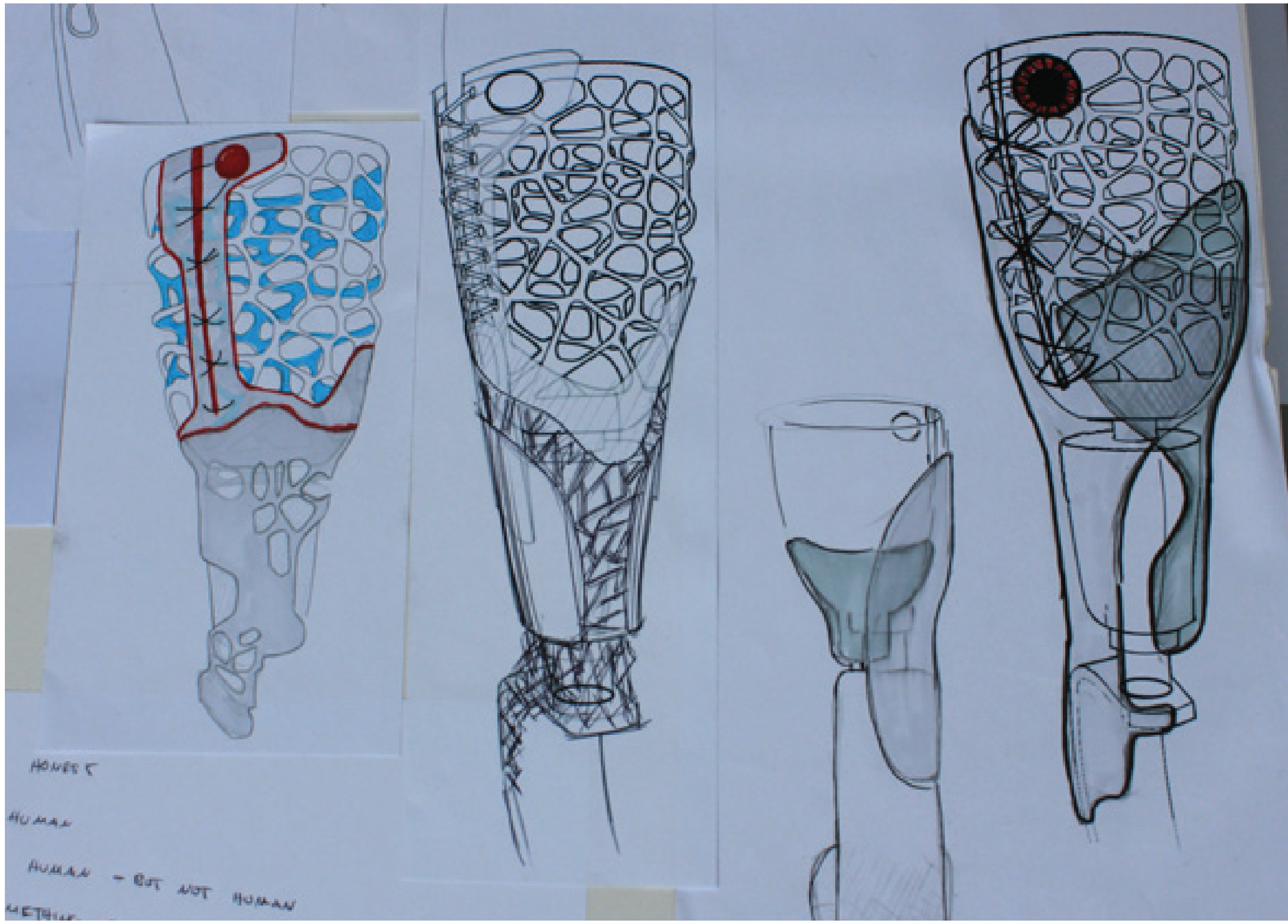

Figure 7: Concept sketches for a futuristic prosthetic limb

Figure 8: IDE students working on prototypes in their studio at the Royal College of Art

The project was planned to involve conceptual development of ideas, acquisition of skills and resources for relevant technologies, prototyping and testing of concepts and design development. The intent was to produce open innovations in the area of Paralympic sports with the practical realisation of ideas from concept to reality. The final critique involved stakeholders, Rio Tinto, C4 television filming the proceedings, the students and course staff. The module culminated with a week-long exhibition of all the teams work, held in the Imperial College London main Entrance.

The format for the module comprised four elements:

1. A one month pre-research phase carried out by project tutors;

2. The four week intensive module - research, conceptual development, experimental work, prototype development build and testing, prototype refinement;

3. Selected model build phase (by Synapse modelmakers);

4. A one week exhibition in the Imperial College London main entrance foyer.

The students were allowed to form groups of three or four by self-selection and were assigned one of four briefs:

Team sports.

Looking at Paralympic team sports activities. Many of these are based on historical traditions and we may be able to propose whole new sports that are designed to highlight Paralympic achievements. Can we use technology and innovative thinking to improve selected team sports or generate new ones? What is a team and do they have to all compete in the same location or time?

Total inclusion.

Considering all levels of disability in sport from the playground to the podium. The focus can be on technology providing equality of competition or looking at new classification models. Inclusive rather than exclusive participation via new models and technologies. Not all disabilities are covered in current Paralympic sports. They may challenge economic barriers to participation of buying sporting equipment.

Paralympian 2016

This is the ‘best possible now’ scenario where students will innovate for the near future harnessing new and emerging technologies focussed through innovative projections about how existing Paralympic activities may evolve. What would be the best new paralympic sport to introduce for 2016?

Paralympian 2056

A future forecast illustrating how a combination of new athletic goals, deep technology forecasts, viewing experiences and competitive experiences can offer challenging thoughts about future Paralympic competition. This theme requires strong envisioning skills and narrative for communication.

RIO TINTO PARTNERSHIP

Figure 9: Paratriathlete Jimmy Goddard and javelin thrower Scott Moorhouse at Imperial College London for the athlete workshops

The Rio Tinto Sports Innovation Challenge inspired by the London 2012 Paralympic Games was an exciting opportunity to work with our long term partner Imperial College London. As well as supplying the metal for the medals at the London 2012 Olympic and Paralympic Games, we were excited that our sponsorship could also make a tangible contribution to Paralympic sport and healthy lifestyles for people with disabilities.
The Innovation Design Engineering students fully embraced the spirit of the Paralympic Games, working with disabled athletes to deliver projects which were not only innovative, but demonstrate understanding and empathy. Most important of all these projects can make a real difference to the life of disabled athletes.

Rio Tinto

Rio Tinto's vision is to be the leading global mining and metals company.
To achieve that ambition we need a rich pool of bright, energetic, and talented men and women across the globe, who are not afraid to dream, who can take others on a journey with them and drive positive change.
Whether it's resourcing the world's need for economic growth or reducing our impact on the planet, we know that tomorrow's leaders will be those who

Figure 10: Students speaking to Jimmy Goddard, Scott Moorhouse and Dr Ian Thompson at an athlete workshop

find smarter ways to operate and deliver sustainable value.
From partnering with world-leading organisations like Imperial College on the Mine of the Future™ to working with communities to empower their people, our eyes are always open to opportunity.

London 2012

We are proud to be the Precious Metal Provider to the London 2012 Olympic and Paralympic Games. Over eight tonnes of gold, silver and copper from Kennecott Utah Copper in the US and Oyu Tolgoi in Mongolia have been provided to create the 4,700 Olympic and Paralympic medals, the most iconic and historic prizes in sport.

http://www.riotinto.com/london2012/

DISABILITY IN SPORT

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Generally speaking, human beings become disabled in three main ways;

From birth, with a consistent, unchanging disability.

From birth, with a degenerative condition.

Through trauma later in life.

In any demographic it is important not to generalise, however there will always be those who - whether born with their disability or who have it thrust on them through trauma, have varying degrees of self-confidence and strength of character. Participative sport and especially that of a team based nature, has an important part to play in the recovery both mentally and physically of the individuals concerned.
It is self-evident that those who have been victims of a recent trauma and, to a lesser extent, those whose degenerative condition has advanced to a debilitating level, are likely to feel disenfranchised from the rest of society, as unlike those born with a disability it is not their normal condition. One who is born with a permanent condition has no recollection of, for example, being able to walk and thus is unable to miss it and treats the current status quo as normal, which for them personally it is. Enter sport into the equation. It has become increasingly commonplace to involve a degree of sport in the rehabilitation of trauma victims to aid their physical recovery. However, whether the participant has become recently disabled or has been for many years, the introduction of sport into their lives can have a marked effect beyond that of the merely physical.
One study in particular (Hutzer and Bar-Eli, 2007) highlights the importance of sport for the disabled in several areas, namely:

(a) performance accomplishments

and functional efficiency

(b) perceived self-efficacy

(c) self-concept and self-esteem

(d) personality disorders, mood

states and locus of control

(e) activity level and social acceptance.

All the above elements will be affected to a greater or lesser degree by the individual's participation in competitive sport. It is likely, however, that b, c and particularly e will benefit specifically from team sports.
It would be all too easy to look at the previous list and compare them to how they would affect the outlook and ability of a trauma victim who is only recently disabled. However this discounts the previous distinction between those possessing a natural self-confidence and strength of character, and those who lack the same. Even those born with a permanent disability may be lacking in self-confidence and for a myriad of reasons may never have been able to integrate into mainstream society. It could indeed be said that for those individuals who have never known social acceptance for instance, that there is a greater benefit to be had than for those who merely - and it is not the intention to belittle the accomplishment in any way - wish to recapture their prior acceptance before their disablement.
Returning to the areas of importance though; firstly the person will, simply through their involvement in the sport gain increasingly in performance accomplishments, as through time they will become more and more proficient in the skills required in their chosen sport. Their increased activity will lend a natural increased functional efficiency to their daily lives; they may find for example an increase in their hand-eye coordination, dexterity or in their stamina.
This will lead naturally to a perceived self-efficacy as they become aware that they are neither constrained, nor defined, by their disability, and that in fact it has opened up possibilities to them which may otherwise never have been available. That is not to say the individual will embrace their disability - that is perhaps too strong a term - but

their acceptance of their circumstances - whether recently altered or lifelong - is likely to be eased by the realisation that their life is not devoid of purpose due to their disability, rather it is an opportunity or challenge to be grasped and used to best advantage.

It is self-evident that anyone, disabled or otherwise, who takes up a new interest - competitive sport or otherwise - will increase their activity level, whether it is Family History and they have to spend time visiting the library etc, or in more active pursuits such as cycling for pleasure. This increased activity in itself will lead to an overall increase in the individual's level of fitness and general health. Similarly, disabled or otherwise if one becomes involved in any activity outside the home there is a natural consequence that they will come into contact with others engaged in similar activities, and thus their social circle will increase.

This is particularly the case in participative sport where the individual concerned, even in single competitor events, will both train alongside, and compete against, others involved in the same sport. In team sports of course this is multiplied by the size of the team involved, and will introduce an element of cooperation into the picture. Common to every sport of course is the wider support team; the coaches, physiotherapists, doctors etc who provide additional input into the individual's development. For some it may be a considerable time since their condition has received more than an annual 15 minutes with a doctor to ensure there is no urgent problem requiring attention, and so the focussed attention of the support team will bring its own benefits outside the sport.

The greatest element particularly in team sport though will be the social element. As proficiency grows the individual will find a greater feeling of self-esteem with the realisation that there is a trust between them and the other

"life is not devoid of purpose due to their disability"

team members, and a reliance on them to fulfil their tasks toward the common goal of winning at the event. Sportsmen and women who are not disabled socialise outside the sport, some team sports being rather well known for their off-pitch socialising, and disabled competitors are no different in this respect; they too will enjoy each others' company off the pitch as well as the comradeship on it.

An extension of this social element is the probability of crossing what may to some be perceived as a boundary between those who are disabled and those not. Particularly in a team which may mix those with congenital conditions and trauma victims, the latter will no doubt have friends and relatives who are not disabled who may be involved in any social gatherings; birthday parties; christenings; weddings. This will lead naturally to those who may not have mixed socially with those who are not disabled - since their disability has been an issue for them - and afford both sides to forge new links of understanding, once more imbuing the disabled person with a feeling of greater self-worth and belonging.

The feeling of belonging, and more importantly of acceptance by others for who they are, is a key element of why team sport in particular is a valuable tool or resource for those involved in the rehabilitation of trauma victims and for those involved perhaps in a less medical role such as those who may run day-care centres. They will be able to pinpoint those who attend their facilities who appear less inclined to engage with other visitors or members and be able to give guidance towards

Figure 11: IDE students trying out Jimmy Goddard's racing wheelchair at an athlete workshop

such activities that will aid the individual in achieving greater social awareness and involvement. Once involved in the sport, this role then transfers to the coach.

The basic role though of a coach at first glance is simple. Train their charge, whether that is an individual or a team, in the skills required to meet the goals of their particular sport. The picture becomes rather more complex on closer examination. Rainer Martens (2004) believes coaching to be more of a multi-disciplinary effort, including such diverse areas as education, physiology, business, and psychology. Of these physiology and psychology are the most important in the context of the disabled novice competitor.

In military terminology the coach in a team sport becomes a 'force-multiplier', that is to say the effect of their actions becomes larger with the more competitors they have access to in the squad. Thus they are able to simultaneously positively enhance the abilities of all the team and develop all five of the areas identified in the 2007 study mentioned earlier.

In summary then, irrespective of the genesis of the individual's current circumstances, there are those who will either find the transition back to their previous involvement in society difficult, or conversely have never had that involvement will find the prospect daunting. Team sports can in a very real sense act as a catalyst to the process of them (re)engaging in society and providing a true quality of life.

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SUITABILITY AND NECESSITY

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We all like to use great products and in order for a product to be described as 'Great' it needs to meet or exceed your requirements and/or expectations. In the Medical Device sector these are identified as 'The user requirements' and the regulatory bodies require evidence to show that these have been met before the device is certified for use or sale.

It is most likely that anyone reading this article either owns, or knows someone that owns an iphone or ipad. The success of these products is largely down to the way that they appeal to such a broad user group, which gives them very large economies of scale. They can also rely upon market feedback from their users to ensure that the product meets with their requirements. The assistive technology market, however is a very focused market with much more specific needs. This means that even products that are successful in these markets cannot benefit from the very large economies of scale available in more general consumer markets. As many assistive technologies are regulated as Medical Devices, the manufacturers must also demonstrate that the products meet with the requirements of the user before they can be certified for sale. The combined challenges of smaller economies of scale and the requirement for proof that the product meets the requirements of the end user, can make it a lot harder develop and bring these products to market. A consequence is that there are generally speaking far fewer and less exciting developments in assistive technologies.

By sponsoring the Sports Innovation Challenge and employing the skills of the IDE students Rio Tinto is helping to overcome these challenges to some degree in order to allow exciting new ideas for sporting aids to be evaluated and tested by elite athletes.

Figure 12: IDE module tutor Dr. Rolf Thomas and module leader David Keech

The following headings highlight some of the issues that IDE students encountered when developing products or technologies for the assistive market.

Suitability of Solution

The level of suitability of a solution is proportional to the level of understanding that the solution provider has of the requirement. The user requirements are both qualitative and quantitative. For example the primary qualitative requirement for a sports wheelchair may be that it is the "fastest wheelchair." This may get captured as a quantitative requirement of the wheel chair with the "fastest top speed." It may, however, transpire through testing that the qualitative requirement "fastest wheelchair" could have been better described using the quantitative term "fastest to reach top speed" or "most manoeuvrable."

Priorities for the User

Without the input of the user to validate the decisions made, there is a real danger of producing a solution that is completely inappropriate. For example, it is a commonly held view amongst the majority of the population, that walking upright is the preferred mode of travel for all people. This can result in too much value being placed on a disabled

Figure 13: IDE students demonstrate their 'Ghost' device to train upper-limb joint position in visually impaired athletes

Figure 14: IDE students quiz Jimmy Goddard about his racing wheelchair and handbike at an athlete workshop

person being able to walk or being upright and not enough on their own requirements. A great deal of research has gone into developing a powered wheelchair that would allow users to climb stairs. The creators were expecting it to be adopted by councils so that wheelchair users could live in ordinary council houses with stairs. This may on the surface seem like a very good solution, however not all wheelchair users want a power wheelchair. Many wheelchair users depend upon the exercise that they get from propelling themselves in wheelchairs and would never wish to sacrifice this for the ability to climb stairs.

Athlete and Equipment as a Complete System

It is easy to overestimate the usefulness of a prosthetic limb or the functionality that it can provide. It is a common misconception that a prosthetic limb will replace much of the functionality of a missing limb. One example of this is the effect that wearing a prosthetic arm may have upon the biomechanics of the wearer. It may seem reasonable to think that if an upper limb amputee wears a prosthetic arm, then it will help to balance the gait during running. Further analysis, will show that the prosthetic is effectively a dead weight unlike the limb that it is designed to replace and consequently the gait will not necessarily be balanced by the addition of a prosthetic. This demonstrates the need to consider the athlete and the device (in this case a prosthetic upper limb) as a complete system. If the athlete and the device are considered as distinct then there is an increased likelihood of the athlete developing an injury as a result of using the device.

Interface Between Athlete and Equipment

A great deal of consideration should be given to the interface between the athlete and any device designed to augment their performance. By the nature of the application there will be a relatively large amount of power transferred by the athlete to or through the device. Poor interfacing may result in discomfort, damage to the skin or other soft tissues of the wearer. If the device is interfacing with soft tissue, for instance the stump of an amputee, then stability and control of the device may be an issue. Surrey University in conjunction with Queen Mary's Hospital in London have developed a system where a screw is inserted directly into the skeleton of the user in order to overcome the afore-mentioned problems.

Market and the Commercial Impact

If there are a large number of potential users (e.g. wound care), then the product may have a good commercial market. This may however mean that a lot of innovation has already been carried out in this area and you will struggle to add anything. You may then develop a solution that you think has a large number of potential users, however it is discovered that although it may help a large number of people world-wide, most of these could not afford to buy it and consequently the market is very small.

Conclusion

The future for product design is very exciting, with many dreams being realised through evolution in technology. The face of society is also rapidly changing through social evolution, with disabled people becoming less marginalised, and exercising a voice rapidly growing in strength. The Olympics are a fantastic platform for celebrating this evolution, and we hope that it will act as a springboard to raise our expectations in seeing more disabled people in all walks of life including product design!

OBJECTS OF EMPOWERMENT

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After a century of existence as prescription medical products, there is an exciting opportunity to interrogate the aesthetics and user experience of many assistive devices to create high value objects of empowerment for the consumer.

Current trends in the prosthetics industry are toward imitation of life using pink plastics to disguise and robotic systems to facilitate life-like movement. The NHS may be commended for making every option available to patients free of charge. However this has liberated manufacturers from addressing the emotional needs of the consumer, focusing instead on a range of sizes and colours in keeping with cost minimisation.

Within the community there are a number of users who reject the philosophy of concealment because it is for the viewer rather than the user. These individuals may accessorise their devices as an act of celebration or avoid using them altogether in public. Wolf Schweitzer, author of the blog Technical Below Elbow Amputee Issues, has expressed his affection for analogue body-powered prosthetic systems, independent of batteries and whirring electronics. He frequently repaints and rebuilds his limbs as experiments in aesthetics and materiality, to explore his sense of self and make himself approachable as a man-machine.

Baroness Tanni Grey-Thompson, one of Britain's most successful athletes, is passionate about the value of technology and design in her racing wheelchairs, enthusing about the virtues of carbon fibre and great paint jobs. She emphasises the importance of variety and choice in wheelchair design, to afford the user both the experience and an identity of independence. Tanni refers to her day chair as being very much a part of who she is, expressed

through a choice of material and colour. She is currently enjoying the bare metal look.
The appearance of assistive devices has the potential to have either a positive or negative effect on social interaction. A medical or disabled aesthetic, in an attempt to camouflage or replicate human form, can be damaging to people's egos and make those around them uncertain how to respond. A better philosophy may be of celebration rather than concealment. New aesthetic options could be used to empower people and attract a healthy curiosity and approachability.
Gender is an important component of identity. In his book Design Meets Disability, Graham Pullin proposes that masculinity and femininity may be expressed through the use of materials and form. Amongst men there is often a preference for materials that give the perception of speed and power. By contrast, according to Holly Franklin inventor of 1-UP one hand hair ties, some of the most successful limbs for women may be those that exhibit jewellery-like qualities or use warm, organic materials such as wood. This she feels would transform her arm into something beautiful and marvelous and affirm her identity as a self-assured woman.
For Holly and others the idea of having a repertoire is appealing. Depending on mood the same individual may feel the desire to blend in or conversely to make bold statements, from one day to the next. In making comparison with the footwear industry, one notices the huge array of options available to the consumer and indeed that not all shoes are about utility but rather self-empowerment, exemplified by the winklepicker and stiletto heel. Even the most functionally enabling technology could borrow from the language and materiality of fashion or jewellery to provide aesthetics with personal meaning for the user.
Dialogue and experimentation are key in this field for helping users to understand what they want and affording valuable insights for designers and makers to develop objects that truly address the human need. The London 2012 Olympic and Paralympic Games are just around the corner. Now is the time to embrace disruptive innovation alongside consumers for positive change - to create assistive and prosthetic device that are both wearable and desirable.

Figure 15-18: Experiments in armwear by Becky Pilditch and Holly Franklin

Figure 19: Johnathyn Owens, Nayoung Kim and Ting-han Chen working at the IDE studio on their futuristic idea of a wing-suit grown from genetic material

Figure 20: IDE module leader David Keech trying out the ‘Augestra’ device to improve audience experience in goalball

INNOVATION STRATEGY

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Figure 21: IDE student Hankak Lee working on sketches of their nanobot surfing concept

“Rich” is the word that has been used most often to describe our Rio Tinto Sports Innovation Challenge project. Rich in inspiration, resources and potential; a veritable recipe for the incubation of ideas. For that recipe, take an exciting context (none could be more so than the Paralympic Games), add a generous amount of expert research, extensively equipped workshops, some ready-to-go electronic toolkits, thirty-six of the most talented design students in the world and innovation must surely ensue? Not necessarily. Innovation cannot be artificially induced; it must grow out of genuine need, and be brought about by those who genuinely desire it. It also requires the often contradictory elements of liberated imagination and practicality. Our first challenge was to frame a project that would allow for both, with enough latitude for a little magic.

We divided the brief up into four segments; Team Sports, Total Inclusion, Paralympic 2016 and Paralympic 2056.

Figure 22: Concept development in progress at the IDE studio

The idea was to enable a very broad spectrum of projects to germinate, from practical component-based engineering of today, to the boundless gaming possibilities of the future. It could also be the birthplace of entirely new sports, radical technologies, and as yet unimagined audience engagement.

These four brief segments were then divided up evenly among eleven teams, three to four students per team. The students were allowed a certain amount of choice in terms of team-mates, but no choice as to which of the four project areas their team received, the intent being to reflect professional design practice; you may choose with whom you work to some extent, but rarely the exact nature of your fee-earning projects. This whole process happened quickly, informally and with more than a hint of the old school playground team picking method. It was a key moment in the project weeks of careful pre-module planning and research by academic staff condensed into a few minutes of deliberately informal serving up of the brief to the innovators.

Another key element to the project was the 'meeting of minds' approach. Generous amounts of contact points between students and leading sports practitioners were built into the module – touch points for innovation. There were two workshops with elite Paralympic athletes, the first to allow the students to hear first-hand the real issues facing the athletes and pick up potential areas for development, the second, a week later, to allow the athletes to comment on the students' work in progress. Again, the intention was to mirror the commercial design world, the athletes providing the innovation context and then feeding back, in the same way that a commercial client might offer a set of needs and then steer deliverables. On top of this there was a field study trip to Bath University, home of the British Paralympic team, and a truly inspiring lecture by Baroness Tanni Grey-Thompson. The threads of inspiration gained from these contacts continued to underpin the students' thinking throughout the module.

This was a project about the physical manifestation of ideas. Innovation becomes most powerful when supported by practical demonstration, and Paralympic sport is not about the theoretical. To this end the students were encouraged to engage with materials from the outset, and to start constructing in 3D even before their ideas were fully formed, using hacked headsets, our pre-packaged electronic toolkits and any structural materials that could be easily and quickly used, including cardboard and string. Spider diagrams were quickly left behind (they were banned anyway), and words quickly gave way to objects.

When, in the final crit we were presented with desert nanobot surfing, a neuro-controlled bobsleigh, and a new prosthetic limb for Scott Moorhouse based on an analysis of bone structure, (to name but a few team submissions) it was clear that innovation had taken place. And a little magic too.

BIOMECHANICS IN THE PARALYMPICS

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Figure 23: IDE student Victor Monserrate working on the electronics for 'Brainsled'

Sports performance enhancement is a multi-factorial activity where psychology, training, coaching, technique, physiology and mechanics all play role. Biomechanics is the study of how the human body is loaded through activity and is one of these key factors. This involves motion, accelerations and deformations. Physiology is closely linked to biomechanics through fluid flow in the heart and lungs, for example, but it is athletic performance that is most closely linked to the biomechanics of the musculoskeletal system. Bones, joints and muscles obviously function in synergy to perform athletic endeavours and these structures can all be considered as mechanical in nature.

Biomechanics in sports is applied to the synergistic aims of reducing injury and increasing performance. There are two main forms of injury that are considered in this regard; these are to eradicate acute injuries, such as a ligament rupture due to a tackle in football or a sporting item striking the athlete, and to minimise chronic, or overuse injuries. The former is a type of failure biomechanics, whereas the latter is a complex form of biomechanics in which repetitive overload is an indicator of likely overuse.

The tissues of the bones and joints all have very distinct biomechanical features and functions. Cartilage serves to minimise friction at the rubbing surfaces of the joints, ligaments tether the bones - the structural members - together to maintain a normal range of motion without dislocation, and muscles are the actuators linked to bones via tendons. As ligaments tether movement, if they are torn then the torn ends are not normally able to come together and effect a repair. Therefore a slight strain of a ligament is a serious injury and significant time must be given for repair. A full tear, or rupture, is career-

Figure 24: RTSIC director Prof. Anthony Bull and Baroness Tanni Grey-Thompson

threatening and requires surgical intervention. Cartilage is biomechanically highly inactive. Damage accumulates and the biological response is too slow to allow repair. Cartilage failure over time results in pain and ultimately arthritis. Overuse injuries of bone result in stress fractures, although bones are more active biologically and therefore some microdamage is beneficial in that repair can result in a stronger bone over time. Muscles are the most biologically responsive and hence training can quickly influence muscle strength; muscles can repair very quickly.

Athletes are by nature competitive and therefore overtraining is a temptation that many suffer from. Overtraining can have significant biomechanical consequences, where microdamage due to training (often a good thing), which would normally have time to biologically remodel and become stronger, is the start of a form of fatigue failure resulting in bone fractures, muscle strains, cartilage wear, and performance loss. However, as is shown above, these different tissues all respond at different rates. A common example of these different rates is where an athlete is able to over-train musculature without the bones remodelling, or strengthening, proportionally. It is known for those who over-train their upper arm musculature to spontaneously produce torsion fractures of the main bone of their upper arm in arm wrestling, for example.

Therefore, it is clear that the biomechanical optimisation of athletic endeavour with reference to minimising injury is important and is subject to fine adjustment through training modifications. This discipline of biomechanics in sport is now a mature science where athlete-specific training is incorporated with knowledge of their physiology and psychology to optimise training and performance. This optimisation is more advanced for able-bodied athletes as the subject-specific nature of their anatomy and physiology tends to be only incrementally different from other elite athletes. It is for disabled athletes where the greater variability in anatomy (such as limb loss), can also result in significant variability in biomechanics.

Hence there is an opportunity for biomechanics, and the interaction of the athlete with the sporting equipment, to effect step changes in performance in disabled sports. There are many examples where this has happened previously and it is likely that this will occur again in the future. One of the most famous of these is that of the blades used by athlete Oscar Pistorius from South Africa. There is no doubt that his running blades are optimised to store and return elastic energy at the appropriate time in the sprinting cycle to optimise biomechanical performance; this is tuned to his own sprinting ability and to the natural biomechanical function of his own legs. This can be achieved by the blades, where others need to train to achieve this through training of the foot-ankle-calf biomechanics. His sport's governing body allow the use of these blades in the Paralympics, but these were initially banned by the IAAF so that he could not compete in able-bodies athletics. This ban has now been overturned and Pistorius has achieved the 2012 qualifying standard for both the Olympics and Paralympics. His equipment is unique to him and is also optimised for his own ability. As a double amputee, the elastic storage within the blades can be balanced to provide a cadence that is optimised for his hip and knee flexion abilities. A single amputee would not have this opportunity for balanced tuning due to the presence of the anatomical foot and ankle and would thus be at a competitive disadvantage in some cases.

Some of the projects in this Rio Tinto Sports Innovation Challenge are specifically focused on athlete-specific biomechanical optimisation through equipment design. This is at an extreme end of user-centred design where disability, biomechanical optimisation and equipment customisation meet. It is apparent that not all designs will conform to the current regulations governing disabled sports, but the biomechanical benefits of these new designs will certainly serve to test the limits of biomechanical performance as well as perhaps even widening the definition of sport, where equipment plays such a significant role.

Figure 25: IDE students on the field trip to Bath University visiting the Sports Training Village for Paralympic athletes

RESEARCH IN PARALYMPIC SPORT

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The technology available for research in sport has progressed massively in recent years and there are some very sophisticated techniques available looking at everything from physiology to aerodynamics to notational analysis. These have been successfully implemented in the majority of Olympic sports – mostly out of necessity, as the margins of victory get smaller and the search for that extra 'edge' becomes increasingly difficult.

However, the application of these technologies to Paralympic sports presents varied and unique challenges. In many cases, adaptation and development of techniques is required to obtain the same data for a Paralympic athlete as for an able-bodied athlete. For example, gait analysis is a well-established field that makes use of cameras to track limb motion and can be used to detect specific patterns during running or walking. There are standardised protocols to identify events in the running cycle and to determine the position of markers on landmarks on the leg. A lower-limb amputee with a prosthetic foot clearly requires an alternative approach though, with different marker positions and a different set of protocols. Additionally, no two people are likely to have the same disability and so trying to build normative sets of data for disparate groups of athletes is difficult, and the variability in technology only adds to the challenge.

Even trying to assess a single athlete with one set of prostheses can be problematic. This is highlighted by two studies that investigated the possible benefits of the Cheetah feet used by the runner Oscar Pistorius and which came to different conclusions (Br ggemann et al., 2008; Weyand et al., 2009). Thus in many ways research in Paralympic sport is still in its infancy; from a scientist's perspective though, the result is that there are many exciting areas that haven't yet been explored (Keogh, 2011) and a number of these are highlighted in this book. New types of feedback are being developed for athletes, with much interest in active feedback through audio or vibration on the skin. This has particular relevance to athletes with visual impairment and there are a number of centres working on this technology. Passive feedback can be just as important though and it is often mentioned by amputees as a feature of their prosthetic they would improve if they could. A related area is proprioception knowledge of the position of your joints and where your body is in space. Whilst some research has been conducted in this area for amputees, the translation into sports training and equipment design is yet to come.

An emerging field which may offer improvements in prosthetic attachment is ITAP (Intraosseous Transcutaneous Amputation Prosthesis) technology. These devices allow direct insertion into the bone and offer benefits in load transmission and reduction of soft tissue damage to the remaining limb (Pendegrass et al., 2006). The long-term usability of these prostheses has not been established though and while they potentially offer a more stable connection, the feedback through the bone may be inferior to a socket in contact with the skin. Active prosthetics are also widely available now and in many cases are controlled by the electrical impulses of existing muscles in the user's body. These open up a new level of functionality not just in everyday tasks but in the sports arena as well. The electrode interface may be inserted under the skin or it may be on the surface and some ideas include the use of head or facial control in cases where athletes may not have any limb function.

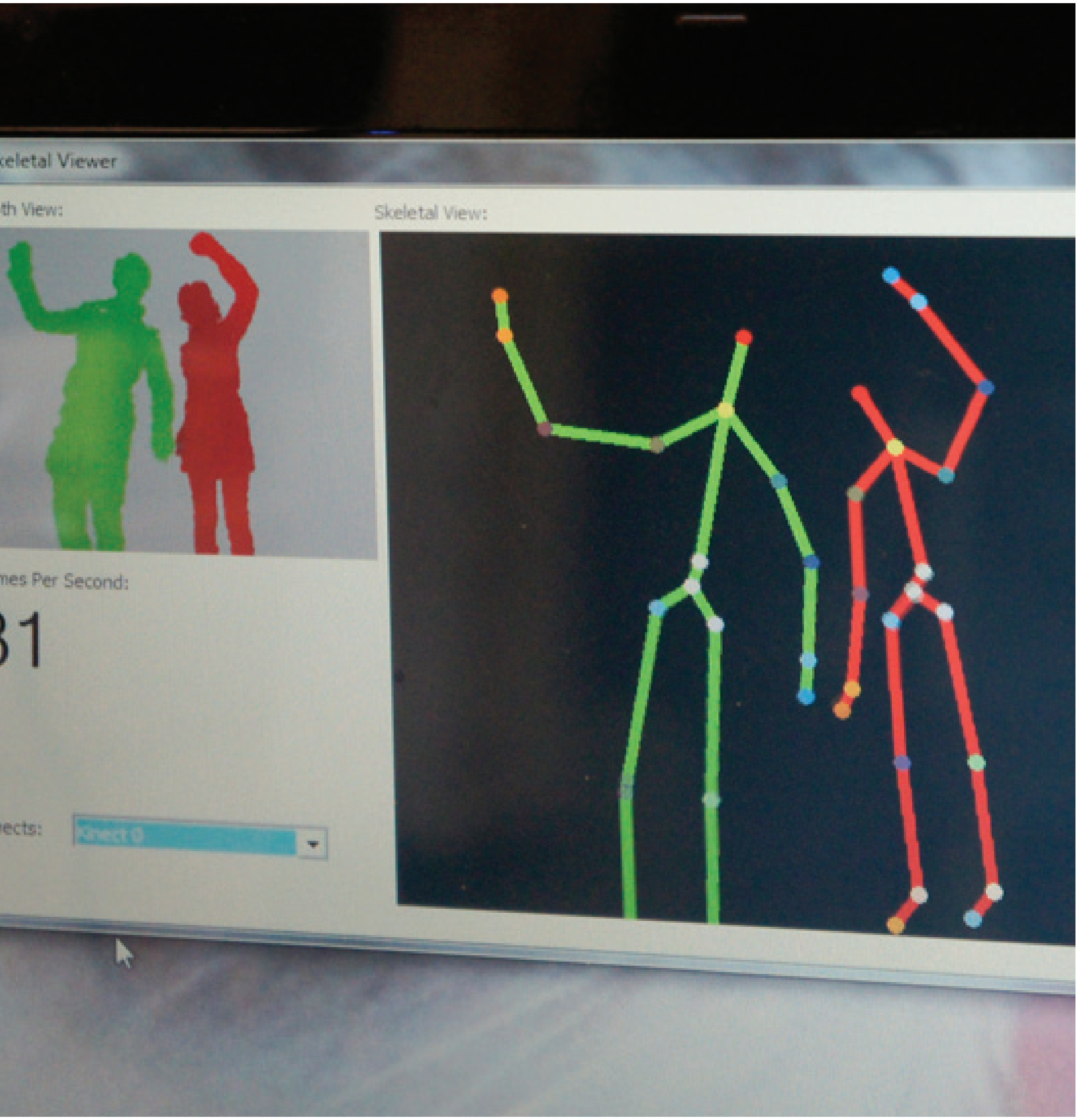

Figure 26: An early test by Ama Williams, James Wright and Tanya Chong using the Microsoft Kinect system to aid rehabilitation

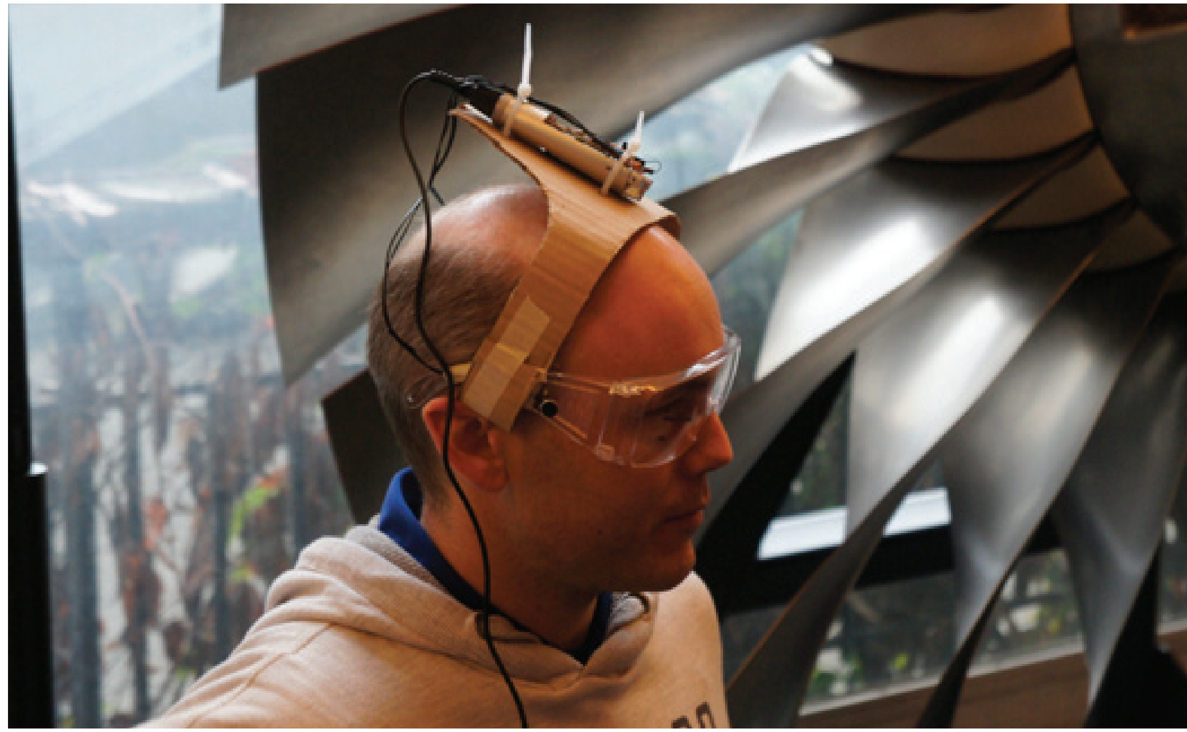

Figure 27: Paratriathlete Iain Dawson trying out new types of audio feedback at an athlete workshop

As we explore new ways of enabling function and enhancing performance we need to simultaneously assess the effect it has on anatomy which is being subjected to new types of stress, from short-term fatigue to longer-term structural change. With such a diverse range of topics awaiting development, Paralympic sports research in the future will undoubtedly lead to many new insights, not just about disability but about the human body in general.

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PHYSICAL TO VIRTUAL

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Sometimes direct action must produce indirect results. Pressing down one foot accelerates a car, pressing the other foot slows it. Paralympians are more open than most to the idea of indirect action, because often the traditional direct action is not possible or even familiar any longer. If one has no legs then alternatives must become second-nature.

Figure 28: IDE student Tim Bouckley demonstrates an early prototype of 'Augestra', their binaural feedback device for goalball spectators

And if one has wings..?

Paralympians are uniquely placed to form the vanguard of next-generation sports, where action and consequence are separate, or thought and action become one.

Liberated from the insistence that sports stars must be a prototypical human morph, it is acceptable to augment Paralympian athletes in ways that would not be allowed of Olympians. Already artificial legs let us run faster than human ones. Wheelchair shooters are more stable than those using legs. Paralympics rules are creating augmented humans.

Augmentation and inclusivity are at the heart of Paralympics; there is simply no other way to enable an athlete without legs to run, and Olympic competitions do not permit augmented athletes to compete. Perhaps it's time to embrace the Paralympic 'augmented games' as the obvious counterpoint to the 'unaugmented' Olympic games.

From a commercial point of view, the popularity of Wheelchair Rugby demonstrates that Paralympic sports can have a widespread popular appeal when they don't attempt to be impoverished versions of Olympic sports. Public enthusiasm blossoms when sports relinquish 'pity' as part of the Paralympic ethos. Isn't there more dignity in being "super-human", than being labelled "disabled"? From an inclusivity perspective, augmentation is not restricted to those with disabilities - anyone could be a Paralympian, and those who use their augmentation every day will have an advantage. Disability becomes enhanced ability. When disabled people have as good or better chances of being superstars, Paralympians will truly deserve our unrequited respect.

If unrestricted mechanical assistance is allowed, then an augmentation 'arms race' is inevitable - anything that assists us can be made to assist us more. It is not possible to standardise prosthetics because Paralympic athletes have a wide range of abilities. Inevitably, there are questions of cost and dignity. Technical development involving people has the potential to risk health and lives (as drugs do in the Olympics). Although disabled people have been quick to adopt experimental enhancements, it would be tragic if athletes felt compelled to become medical experiments in order to compete. There is also a question of cost - better funded athletes could buy their way to victory (as velodrome cycling demonstrates). The flip-side of this argument is that athletes who undergo and fund augmentation development are benefitting an entire community. An augmentation competition would spur the development of assistive technologies, in the same way that many of today's car technologies emerged from motor racing. Perhaps the methods used to keep drivers safe within the technical arms-race of Formula 1 could be used to keep athletes safe. Budget caps and medical inspections would limit dangers without restricting the ability of new ideas to be developed, that have the potential to benefit everyone.

Such restrictions may be simpler than they seem. Acknowledging that technology ages and breaks faster than people, it could be mandatory that all augmentations be removable and non-damaging. To ensure relevance, it could be compulsory that the wearer be able to perform certain everyday tasks.

It's time to re-imagine the Paralympics as an equal counterpart to the Olympics. One that looks to the future, just as the traditional Olympics looks to the past.

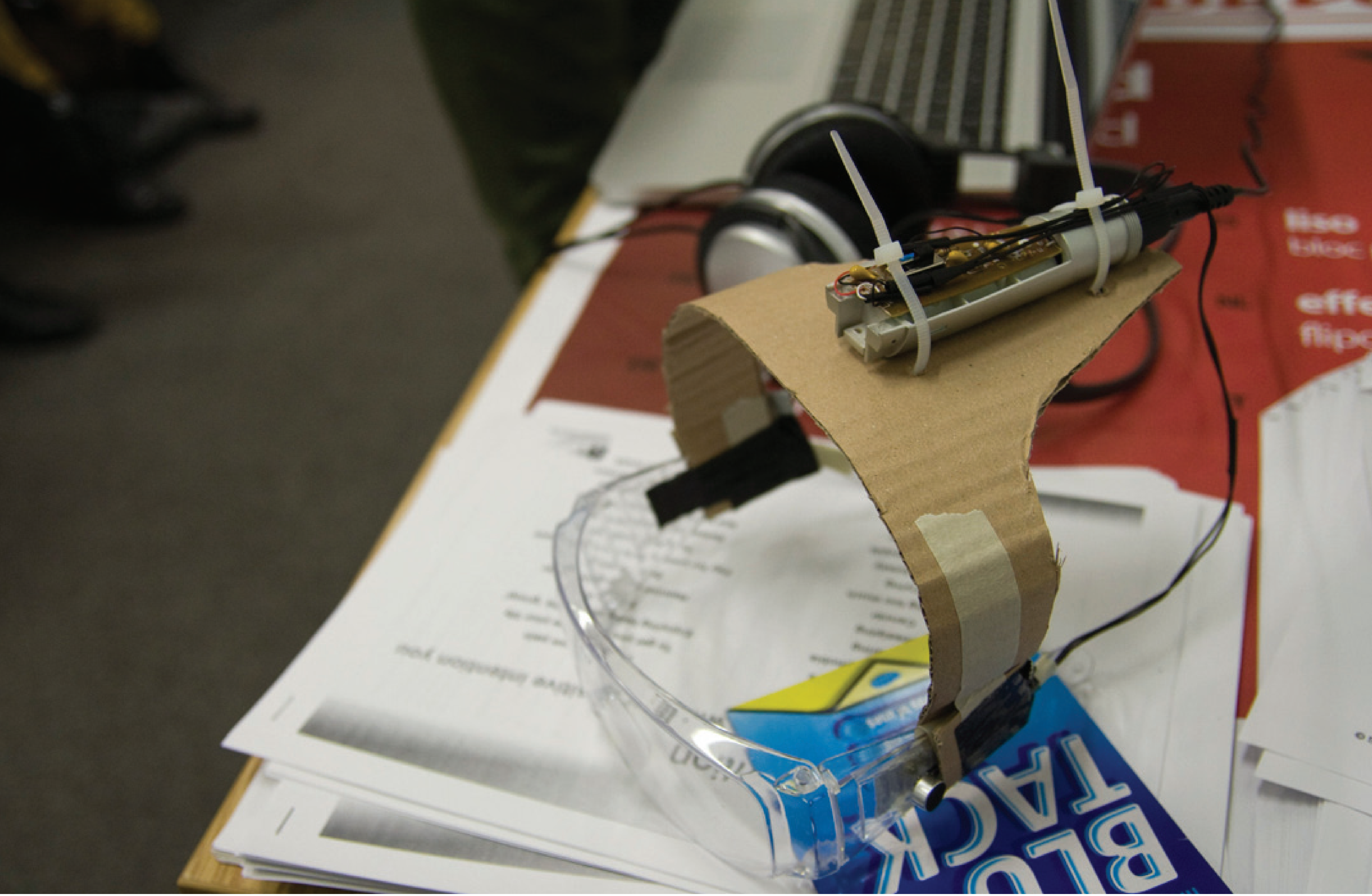

Figure 29: A close-up view of the Aug-cestra prototype that uses a dismantled stereo microphone to provide binaural sound from a goalball player

Figure 30: The Otto Bock Michelangelo Hand - an example of current state of the art prosthetics. Photo courtesy of Otto Bock healthcare products GmbH

FUTURE OF PROSTHETICS

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After WWI the German prosthetisist Otto Bock initialised what is now known as the Orthopaedic Industry. Due to thousands of returning war veterans needing prosthetic devices for a successful re-socialisation Otto Bock built up the first series production of prosthetic components in the world. By applying innovative materials from the chemical industry in the 1950's prosthetic devices became lighter and took on a more natural form. A major improvement took place during the 1960's when Otto Bock developed the first myolelectric arm prostheses, a muscle signal controlled device (www.ottobock.com).
It took another few decades to recognise the need for further developments within the prosthetic industry. Ironically, once again international conflicts led to the latest investments in improving prosthetics. With the access to more economical high-tech fabrics used in body armour combined with an improved army medical training, the survival rate of modern soldiers increased by 90 percent. (www.military.com) The burden of this critical improvement however is the increase in numbers of soldiers experiencing traumas and the loss of a limb. Together with the prosthetic industry and governmental institutions such as the Defence Advanced Research Projects Agency (DARPA) the story of modern prosthetics started to be rewritten.

Figure 31: An Otto Bock User demonstrating the dexterity of the prosthetic hand. Photo courtesy of Otto Bock healthcare products GmbH

In 2004 I joined the company Otto Bock as an in-house designer with the task of designing a high-tech myolelectric controlled hand prosthesis. During this time I took part in several projects shaping the future of modern prosthetics. With science exploring the potential of neuro controlled prosthetic devices Otto Bock became an industrial partner with DARPA in the development of the multi- million US$ "Revolutionising Prosthetic" program. Apart from a multi degree of freedom prosthetic arm, a novel surgical procedure called Selective Nerve Transfers was explored. For the first time an economical viable method of re-attaching existing nerves in the amputee's upper limb to bands of muscles in the chest has been realised on European soil. Within 6 months after the operation the patient's muscles could be contracted by just thinking of former arm movements and the amputee also regained tactile sensibility allowing the design of a feedback interface.

As an in-house designer I could also help change the image of prosthetics first hand. The Michelangelo Project is the first prosthetic hand available not only in a naturalistic look but also with a transparent cover exposing its futuristic look.

With the Rio Tinto Sports Innovation Challenge students showed that there are also other incentives for creating innovative prosthetic solutions. In a discussion between a group of students and elite athletes the conversation led to the idea of creating a self tightening triathlon cycling shoe. A true improvement for people with cerebral palsy but also a product solution with a high potential for a broad market - devices for an inclusive use blurring the boundaries between abled and disabled!

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Figure 32: New prosthetics offer many advantages - gripping items such as a glass can be very difficult, if not impossible, with a traditional prosthetic hand. Photo courtesy of Otto Bock healthcare products GmbH

Figure 33: A further example of an action which is now possible but would not be using a traditional hook-based prosthetic hand. Photo courtesy of Otto Bock healthcare products GmbH

Figure 34: IDE students learning about the equipment Iain Dawson uses for paratriathlon

ATHLETE WORKSHOPS

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Figure 35: IDE student Martin Jaere trying out goalball during the Bath University training village field trip

The Rio Tinto Sports Innovation Challenge provided Innovation Design Engineering (IDE) students with an extraordinary learning opportunity to develop their skills in 'empathic design'. The foundation of this approach is seeing people, who may benefit from a new design idea, as equals in the creative process and involving them as valued partners at all stages of development. Finding design partners can be time-consuming and so we were delighted when four elite athletes with disability accepted our invitation to participate in not one, but two, workshops with IDE students.

The first workshop took place in week one. At this stage, students had already carried out a preliminary study of secondary resources that, in combination with their briefs, helped structure questions about the athletes' lives, their training regimes and individual sporting challenges. The athletes' enthusiasm was compelling; all four of our guests had brought pieces of their sports equipment with them including modified racing bicycles, hand cycles and prosthetic sprint feet. These they demonstrated and then through sensitive questioning from students – considered their issues in new ways. Early notions were blown away, as these latent needs and aspirations were unlocked. The first workshop was a revelation, inspiring students to look at new areas as well as providing a rich resource of insights on which to reflect and analyse.

In the ensuing week, students extracted key insights from their findings and developed them into design opportunities, visualising their concepts and building simple 'sketch' prototypes. Our design participants returned for a second workshop at the mid-point of week two. Together with students' groups, the athletes tried out prototypes, evaluated and helped to refine concepts, creating alternative solu-

Figure 36: IDE students inspecting Jimmy Goddard's racing wheelchair at an athlete workshop

tions and paving the way for students to develop their projects.
We are hugely grateful to our design participants - Iain Dawson, James Smith, Scott Moorhouse and Jimmy Goddard - for their dedication and openness. Thank you.
In addition to the workshops, a cohort of students visited the Sports Training Village for Paralympic athletes at the University of Bath. Students experienced a full tour of all facilities and looked in more detail at equipment, such as a snowboard start gate, an eye tracking device, shooting range, and the human performance laboratory. During the tour, students had an opportunity to try their hands at goalball and sitting volleyball. The visit ended with a Question and Answers session with Duncan Rolley, Performance Manager at Paralympics GB. Duncan explained that functionality is paramount, but aesthetics are also important. He also spoke about the apparent equity issues with accessibility to technology in sport for people with disability.

Thank you to Greg, Mike and Jenifer for hosting our visit to TeamBath.

Figure 37: IDE tutor Andy Brand leading the discussion with paratriathlete Jimmy Goddard

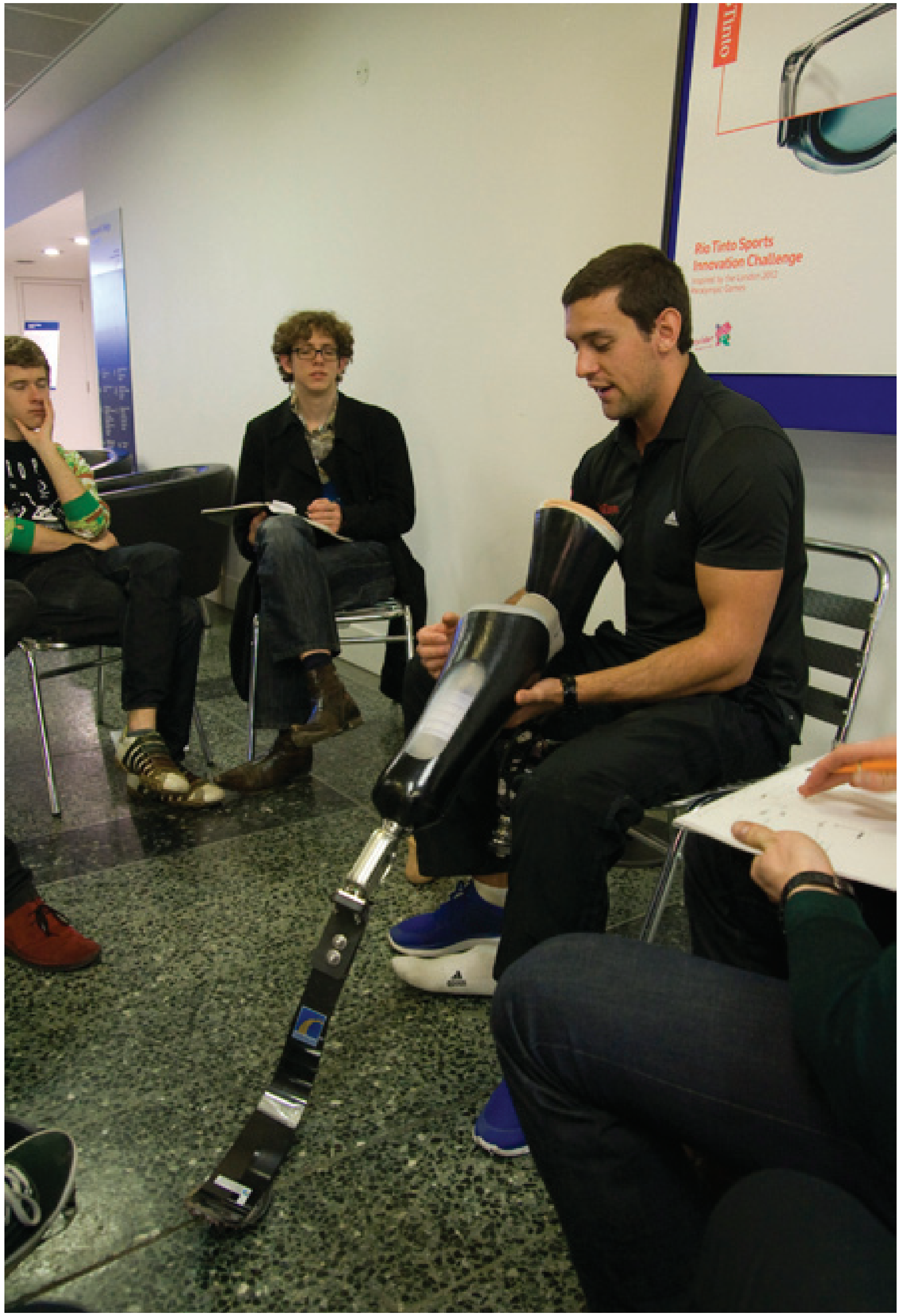

Figure 38: Javelin thrower Scott Moorhouse explains the features of his customised prosthetic leg

ATHLETE TESTIMONIALS

SCOTT MOORHOUSE

Javelin, Lower limb amputee

With London 2012 expected to be the best Paralympic games yet, it is exciting to see the attention placed on future Games as well. Paralympic sport is evolving year on year, however the technology that aids athletes' performance is still in a very infant stage and the projects at Imperial London College, supported by Rio Tinto, have a structured approach that is looking to tackle some of the main issues currently facing athletes. I am thoroughly impressed by the enthusiasm and ideas displayed by the students and strongly believe some of their ideas could be part of the tools that are used to aid para athletes in the future. It is a very exciting time - watch this space!

Figure 39: IDE students noting the features of a liner from a prosthetic leg

JIMMY GODDARD

Triathlon, Spinal Injury

It was really fantastic to be involved in the Rio Tinto Sports Innovation Challenge get involved with the work-shops. Interacting with the bright young students was both fascinating and a real honour. I can't wait to see the creative ideas they come up with to further improve the experience of Paralympic sport for the athletes and the spectators.

Fiqure 40: Jimmy Goddard fields questions about his racing wheelchair and handbike

Figure 41: IDE students trying out equipment such as a dynamometer in the human performance laboratory at Bath University

Figure 42: Triathlon Paralympian James Smith demonstrates his racing bicycle to IDE students.

JAMES SMITH

Triathlon, Cerebral Palsy

I'd like to thank Rio Tinto and Imperial College for the opportunity to take part in such a wonderful project, to have the country's emerging engineers working with a high level company like Rio Tinto to bring innovative design and engineering into disabled sport, which will be a great benefit for all disabled athletes. The ideas the students have come up with over the last couple of weeks have been inspiring, mind blowing! I'm so excited, these ideas could revolutionise Paratriathlon. With such a broad classification system within Paratriathlon these ideas could make the competition more equal within each category. Making the competition fairer, closer, more competitive and exciting to watch, which will in-turn bring more athletes into the sport. The students' ideas would help reduce/negate the athletes disabilities within transition and out on the course.
I am really interested in taking some of these ideas forward as this could well be ground breaking and a stepping stone for equality across many athletes within Paratriathlon and other sports.
I met some amazing people on the Challenge. To have this brain power working on projects to make lives easier within sport and to make it more accessible for disabled athletes is really inspiring and encourages me to perform at my highest level. Hopefully in the future I could be using one of these projects in competition.

IAIN DAWSON

Triathlon, Visual Impairment

I have thoroughly enjoyed being part of this innovative project at Imperial College. The students have been easy to engage with and have developed some great ideas, some of which could well play a future role within Paralympic sport and encouraging active lifestyles for people with a disability.

Figure 43: Iain Dawson finishes assembling his tandem bike, used in paratriathlon by visually impaired athletes

Figure 44: Iain Dawson tries a student developed prototype

MORPHOLOGICAL ANALYSIS

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Figure 45: Concept development sketches for the 'Brainsled'

Morphological analysis is a matrix based technique for assisting in the generation of concept solutions. Originally developed to assist in the American aerospace technology acquisition and research programme during and following the second world war by Frank Zwicky, morphological analysis has since found many applications, principally in science and technology related fields. This short note describes the principles of the technique for generative activity and its value in the conceptual phase of a project along with its implementation in the Rio Tinto Sports Innovation Challenge to encourage consideration of alternative sport forms.

Idea generation and creativity are widely regarded as worthy attributes in our personal and work-based activities. Creativity can be described as 'the ability to invent or develop something new of value', a definition adapted from Boden (1990), where the term value can be applied to either financial or societal aspects. Creativity of course occurs in many areas of our lives from art, music, architecture, in science, engineering and product design to name but a few. Idea generation is seen as critical in the success of businesses and commercial activities. The Cox Review (2005) identified that 75% of company turnover in UK based industry stems from products developed within the previous five years. This indicates how important new ideas are to wealth generation. Idea generation and the implicit or encouraged creativity that occurs to facilitate this is therefore important.

The early stages of design where the major decisions are to be made is sometimes called conceptual design. During this phase ideas are developed about how a product will function and what it will look like. The process of conceptual design can be described as the definition of the product's morphology, how it is made up and its layout. A creative method is a process that can be used to assist in a given task that supports idea generation and the innovative solutions. Examples of creative methods or techniques include brainstorming, analogies, new combinations and synectics. Creative methods can be used to aid the conceptual design activity. A wide range of creativity tools have been developed and reported in the open literature, see for example Childs and Tsai (2010) with hundreds having been identified. A creativity tool is not a design procedure, providing a step by step guide, but instead can be viewed as a tool to assist a task.

Morphological analysis is a tool that can be used to generate additional ideas for product concepts that would not normally spring to mind. The tool involves considering the function of a generic solution to a problem and breaking it down into a number of systems or sub-functions. The next step is to generate a variety of means to fulfil each of these systems or sub-functions. The sub-functions and potential means of fulfilling each of these sub-functions are arranged in a grid. An overall solution is then formulated by selecting one means for each sub-function and the combination of these forms the overall solution. The grid can be filled by text or by sketches depicting the potential means of fulfilling the sub-system requirement (Childs (2004)). The tool relies upon the user's selection of sub-function options to synthesise an overall solution or set of possibilities. The user can explore the design space systematically, using their experience to guide the outcome, or experimentally.

Feature	**Means**								
Competitive Space / Location	Indoor - small (<20m^2)	Indoor - large (>20m^2)	Outdoor - field/park	Outdoor - river/lake/sea	Outdoor - hill/mountain	Virtual			
Surface conditions	Tarmac / Synthetic Track (e.g PU)	Grass / mud	Sprung floor	Snow	Water	Padded floor	Ice	Air-borne / suspended (i.e no surface)	
Participant(s)	Solo	1-to-1	2-to-2	2 Teams (3+ players)	Multiple Teams				
Competing Objective	Attain most [points, objects, height, lifting weight]	Attain least [points, eg Golf]	Fastest [over prescribed time period or distance]	Fastest [peak]	Farthest / Longest	Most efficient [attain most with least input]	Shortest [distance]		
Duration	Single action	Sequence of actions (in short time period)	5 - 120 minutes	1 day	Several days	As long as it takes to achieve competing objective			
Mobility / propulsion	Unassisted - walk, run, jump, swim, throw, roll, spin	Assisted by aide or team mates	Assisted by equipment, self-powered (e.g. pole vault)	Ride an animal (e.g horse)	Ride piece of equipment, self powered (e.g. bicycle, wheel chair)	Ride piece of equipment, powered by external force (e.g. sail boat, skis)	Ride piece of equipment, motored (e.g. motorcycle, car)		
Required Motor Movement	Walk	Run	Jump	Swim	Throw	Roll / Spin	Hit	Dive	Pedal
Movement constraints	None	Specific pattern of body movement (e.g. trippled jump)	Opposed by competitor	Between obstacles	Opposed by weight	Limited movement under specific conditions (e.g. cannot move if holding ball, pass backwards only)	Over obstacle(s)		
Participant's energy transferred to…	Direct to surface	Spherical Ball	Non-spherical Ball	Streamlined projectile	Non-streamlined projectile	Sliding object	Wheel	Ski / blade	
Participant's energy transferred by device…	Hand /Arm (direct transfer)	Foot / Leg (direct transfer)	Head (direct transfer)	Torso (direct transfer)	Racquet / Bat / Stick	Mechanism (e.g. linkage, pedal)	Spring device (e.g. pole vault, bow)	Augmentative device (e.g neuro-signal processing, IMU, optical recognition)	
Participant's transferred by body part…	Hand / Arm	Foot / Leg	Head	Torso	Lower body	Finger	Eyes	Tongue	
Target type	Area on playing surface	Target, elevated above playing surface	Between vertical posts	Hole in/off playing surface	Part(s) of opposing participant	None			
Target protection	Dedicated goal keeper(s)	Anyone on team	Target may be moved	Opposing participant may parry / block / deflect	None				

A morphological matrix was developed in advance of the module in order to enable the students to explore design options rapidly.

Typically developing such a chart is somewhat time-consuming and can easily take up a good part of day in order to consider what suitable subsystems should be defined and to then generate a wide variety of means to fulfil each of these.

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DESIGN NARRATIVE

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Figure 46: Students test a prototype headset.

We are all hard wired for stories. It's central to the way we communicate, think and develop ideas. I see it in the rapt concentration of my daughter when reading to her at night. Despite the availability of easier distractions such as TV, games and the Internet, a simple spoken tale is still captivatingly compelling.

Story telling is one of the oldest and most powerful forms of conveying ideas and as a route to developing thought. In a pre-written world, verbally passed on stories evolved as mechanisms to capture imagination, articulate complex messages and provide an effective vehicle for recall.

Stories couch ideas in a human and personal frame:

"If this speaks to me in a way that I relate to, I will engage in the idea, understand complex ideas in ways I will remember and be able to articulate."

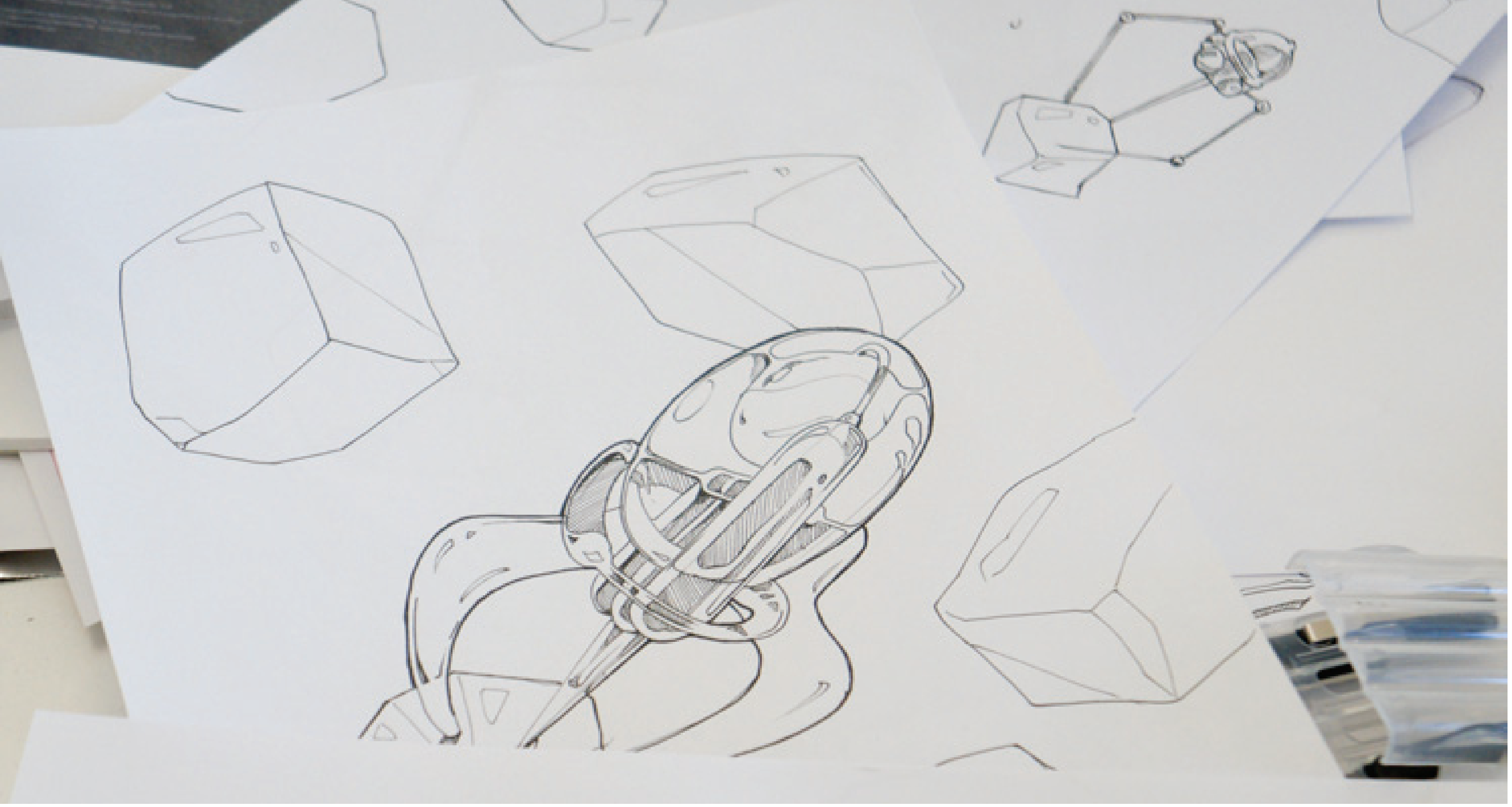

Figure 47: Student brainstorm sketches

As a design tool, narrative can be an incredibly powerful way for the designer to provide context for the brief, develop creative thought process and test the solution against what is usually a complex set of criteria. In this module the students were encouraged to create scenarios and background stories so that they could use narrative as a tool to construct and structure project ideas, then as a means of exploring the concept and ultimately as an engaging way to communicate their project at the critique and exhibition.
Instinctively a designer's starting point is to build on their personal relationship with the subject matter, at least subconsciously. This can have limitations when the focus of the project is not precisely in their field of experience. The Rio Tinto Sports Innovation Challenge provided a rich source of inspiration but also placed students outside their immediate zones of personal experience, notably that of understanding the dynamics of disabilities or the lives of, and challenges facing paralympic athletes in their sporting life. The students' initial opportunity was to take advantage of the fantastic resource available within the module in the form of hands-on workshops with four paralympic athletes (each with personal stories), a visit to the Department of Sport Development and Recreation at the University of Bath and one-on-one tutorials with the wide cross section of visiting lecturers and tutors, with relevant experience and expertise.
This immersion phase allowed students to "imagine" themselves at the heart of the athlete experiences and script their own detailed narrative framework on which to base their project.
This was especially important given the deliberately wide remit of the project brief (team sports, total inclusion, 2016 and 2056) and the many different manifestations that the project could take. Approaching the project through narrative helped quickly ground ideas and create tangible scenarios.

Two examples

Constructing believable user centric scenarios was an effective way of providing relevance when future projecting to 2056 and this was very well explored with the Avian Sport Group who set the scene by describing a new context for new age prosthetics driven by the need for personal empowerment through body image and then ascribing new levels of performance functions from there.
In this case their adaptation of user narrative as a way of defining qualities such as visual language was inspired as future technology threatens to be so revolutionary that production methods will leave no imprint or clue in the visual appearance of a product. In other words not only will "form no longer follow function", but function could be entirely transformed and unrecognisable. However human need will likely remain something of a constant and a good route to describing believable future products.
The Empara Group developed ever more detailed levels of narrative as they explored user scenarios for their interactive sports rehabilitation tool. This approach ran alongside their in depth testing of an electronic feedback rig and directly fed prototype insights into a growing user scenario. In fact their pursuit of narrative as a design tool allowed the design to evolve in the way it did away from conventional product led output and into what was essentially a non-product a software package that subverted standard X-box hardware. By the end of the project they had not only created an end to end story of how the rehabilitation tool benefits the patient, but had also mapped out the initial consultation process with NHS and packaging to explore how the design was presented to its customer. As a consequence of this approach the presentation of their project at the final critique was not only engaging, well thought through but also immediately credible.

Figure 48: People begin to assemble for the opening of the Sports Innovation Challenge exhibition

CURATING

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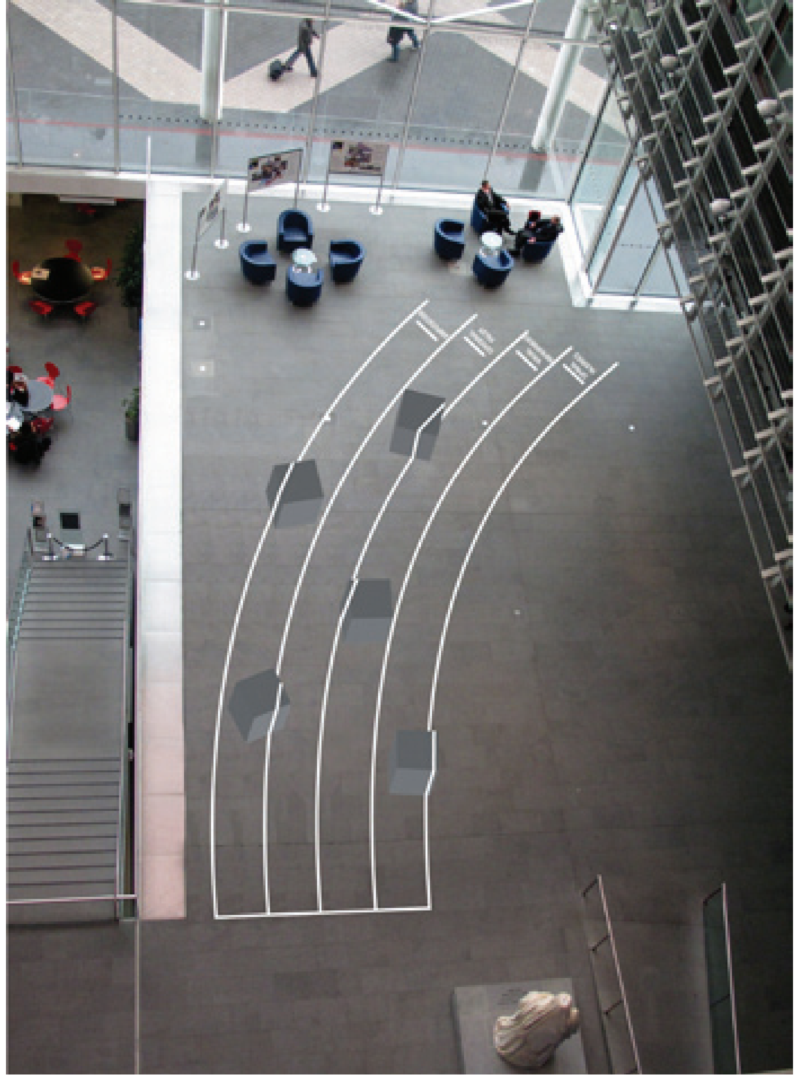
An exhibition of the student work was planned from an early stage in the project, providing a focal point for experiencing the outcome of the project. In one of the first project team meetings we viewed the space where the students' work would be exhibited. One of the tutors mentioned the idea of using running tracks to visually link the exhibition to the field of sports. The spark to an exciting one week long exhibition was lit.

The exhibition space chosen was the main entrance foyer of Imperial College on Exhibition Road designed by the architect Norman Foster. When entering, the grey coloured granite floor area is overlooked by a statue of Queen Victoria and opens the view to the huge cylindrical metal wall housing lecture theatres of the Imperial Business School. The task of the curators was to pro-



Figures 49-51: The exhibition at Imperial College begins to take shape

vide an appropriate platform for each project group to exhibit their work and also to blend the exhibition subtly into the designated space. The concept was very simple; four running tracks marked by a contrasting white vinyl tape on the floor marked the exhibition area. Instead of athletes, cubic plinths carrying the exhibits were positioned along and beside the tracks. Each track represents one project area defined within the project brief and the plinths represent runners competing in this sports innovation challenge. To give the whole layout a visual link to the upcoming 2012 Paralympic Games and underline its distinctive dynamic and edgy graphical appearance the plinths were placed at slight angles across the tracks. Where the vinyl on the floor meets the black MDF cube it travels up the sides and uses cut out letters to additionally label the plinths.

To support the 100-word project descriptions two high end projectors, provided courtesy of Epson, were used for screening of each project group's two minute video, that was a primary deliverable along with the prototypes.

With a low environmental footprint in mind, all plinths were designed for disassembly after use. Roughly 50 m2 of black board was joined by 600 black dry wall screws enabling the reuse of the material for future events or just for more exciting student projects.

Figure 52: Viewers interact with the prototypes designed by IDE students.

Figure 53: Students, athletes, professors and guests mingle in the Mechanical Engineering concourse

Figure 54: The exhibition is complete

THE ELEPHANT ON THE CARPET

A BRIEF DISCUSSION ABOUT THE IMPORTANCE OF USER INPUT:

I just felt that I should point out The elephant on the carpet (a term often used in social work to describe the potentially embarrassingly obvious). This is the fact that none of the design students have obvious disabilities e.g. there are no wheelchair users. This could be used to imply that the Design world is more prejudice against disability than the Olympics.
Obviously there has been no prejudice at work, and everyone has tried very, very, hard to be as understanding and as accommodating as possible, however I think you will agree that there is a little irony there.
Perhaps being the only tutor with an obvious disability, I am not the first to notice, but simply the most empowered to raise this point. I just felt that it was my duty to raise this in peoples minds, so that we don't look flummoxed if someone else makes the same observation at the show.
The students pointed out that IDE would be a very difficult course for wheelchair users due to the geographically challenging timetable. On the positive side, perhaps there is some EU finding available for making IDE more wheelchair friendly.

Looking forward to the show.

Rolf Thomas

To me the most obvious response, should anybody raise that issue, would be to highlight the great lengths that everyone involved in the project has taken to actively seek input from the end-users, both in terms of the Paralympic athletes who have taken tutorials, Baroness Grey-Thompson and others who gave presentations, visiting Bath, and those such as you and I who although not professional athletes have experience of living with a disability and can speak from that point of view as spectators of the various sports as well.

Julian Hall

Figure 55: 'The elephant on the carpet'

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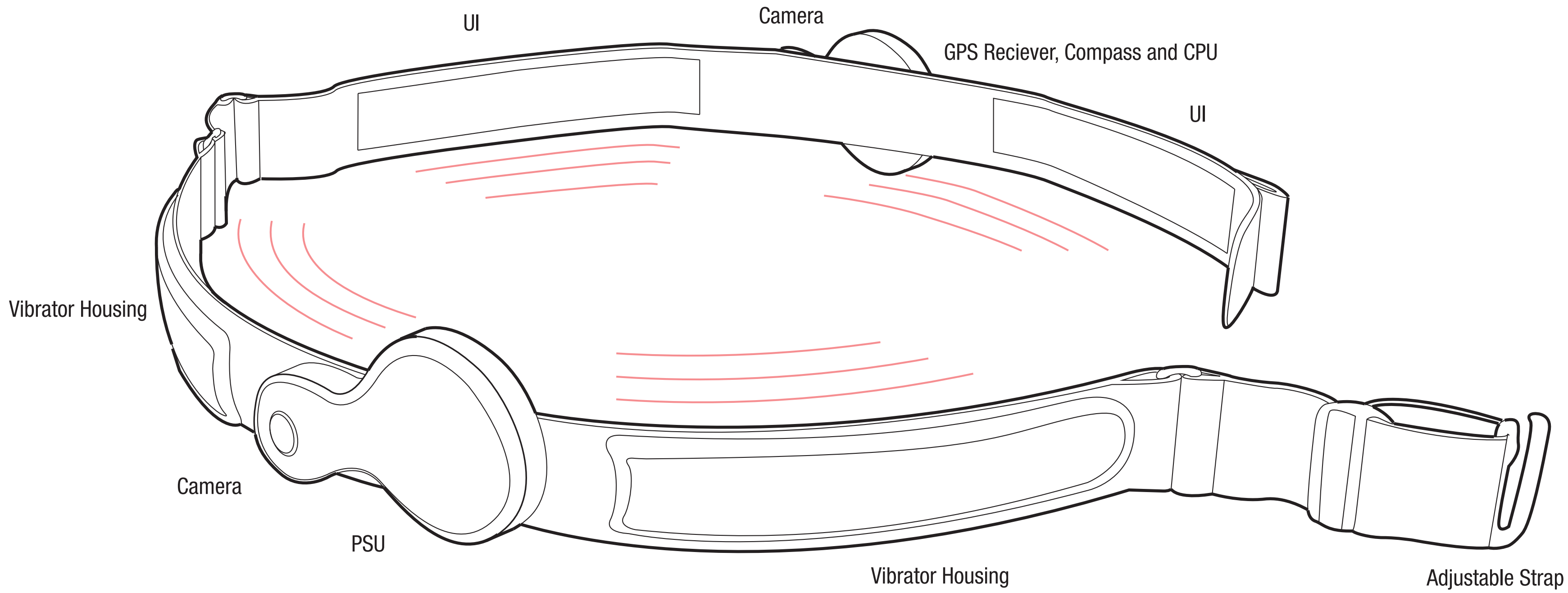
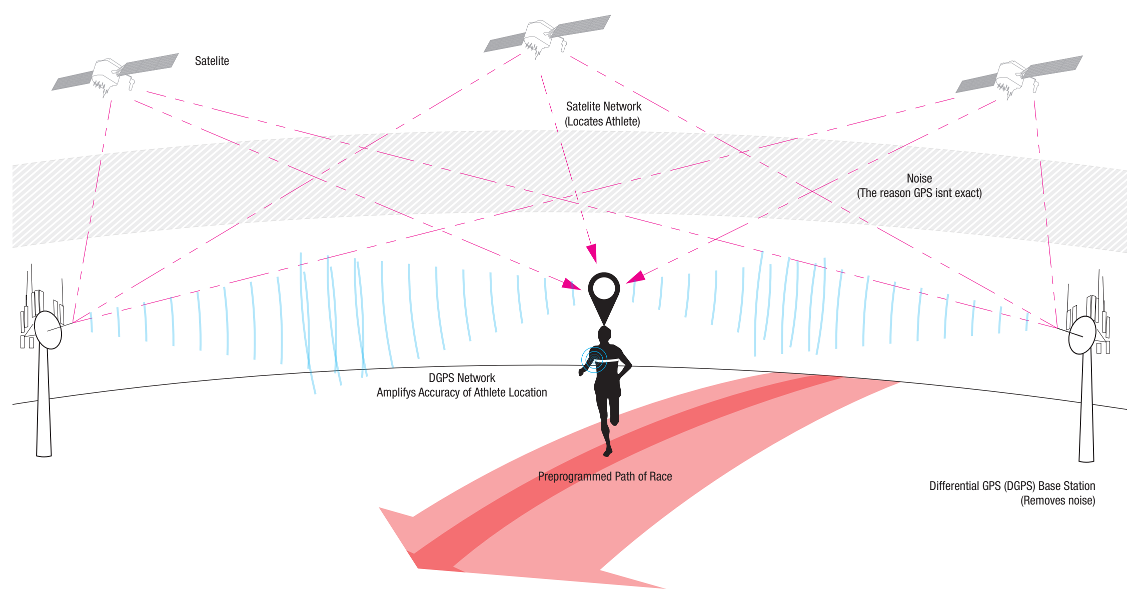
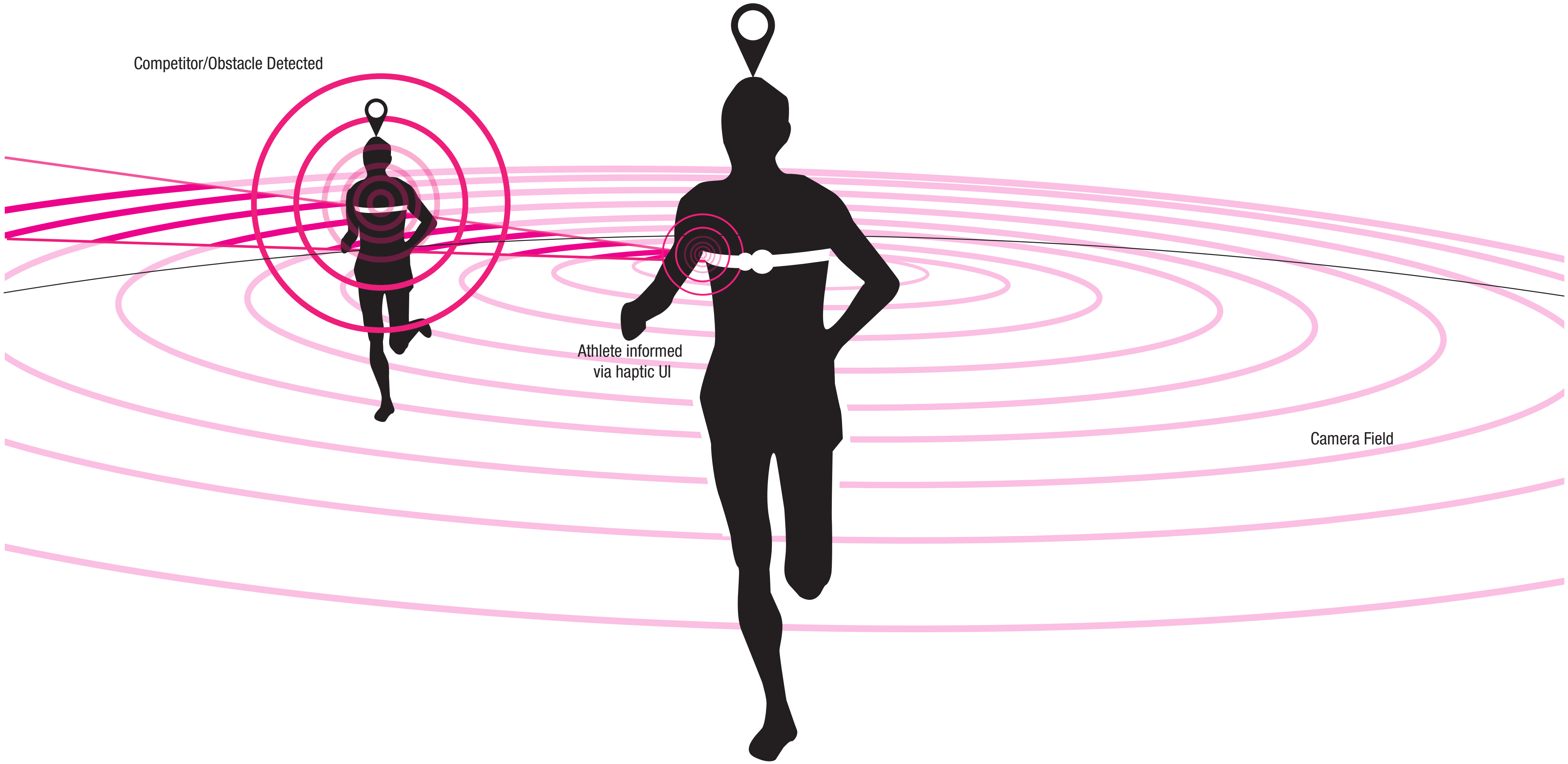
HAPTIC VISION

CHIN-WEI LIAO
DANIEL MCLAUGHLIN
IGOR SAFRONOV

Group 1 was quickly drawn to early insights that suggested they challenge the team sports brief. Inspired by vision impaired Paratriathlete; Iain Dawson, who is required to compete an individual event bound by a lanyard to a guide, the group explored systems and devices to give the athlete more control and autonomy over his performance.
Driven by what locating and sensing technology could provide to vision impaired, the group pursued a method focused on haptic (touch) communication tools that act as guidance aids for vision-impaired racing.






Competitor/Obstacle Detected
Athlete informed
via haptic UI
Camera Field

RAINBOW TOUCH

MI EUN KIM
MARTIN JAERE
NORIYAKI MAETANI

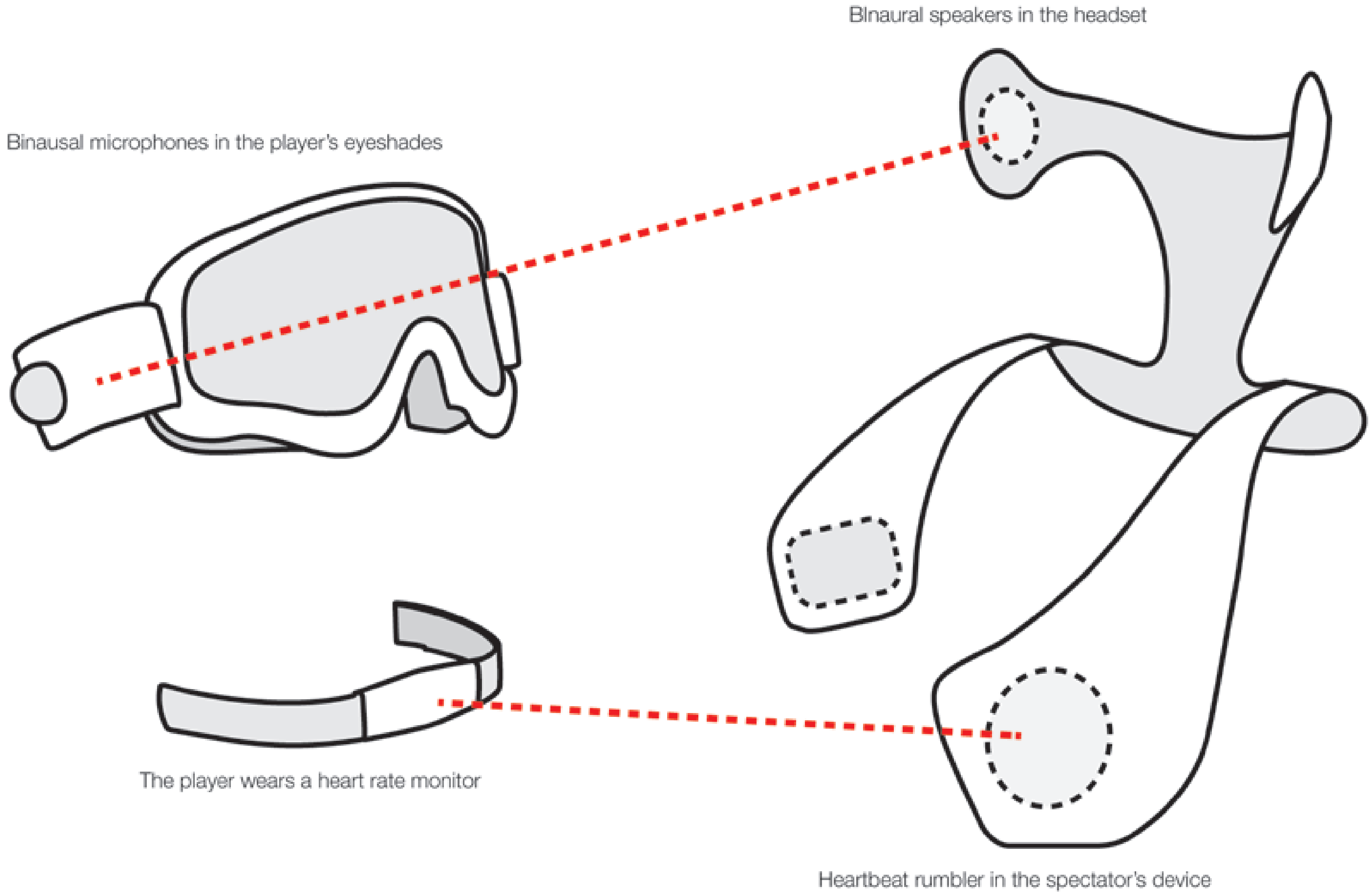
Rainbow Touch is a colour-to-texture translation system especially designed for visually impaired athletes to recognize the colour of their team uniforms. We believe this can help to build team spirit, not only for the players, but also for visually impaired fans that can wear their favorite team's clothing and sense the team colours through touch. Rainbow Touch uses textures based on dots and lines in variable size and thickness to represent colour based on the continuous spectrum of visual light. Rainbow Touch can be the basis of a new universal colour-to-texture translation language.


7
10
RAINBOW TOUCH
TEAM SPORTS
TEAM SPORTS

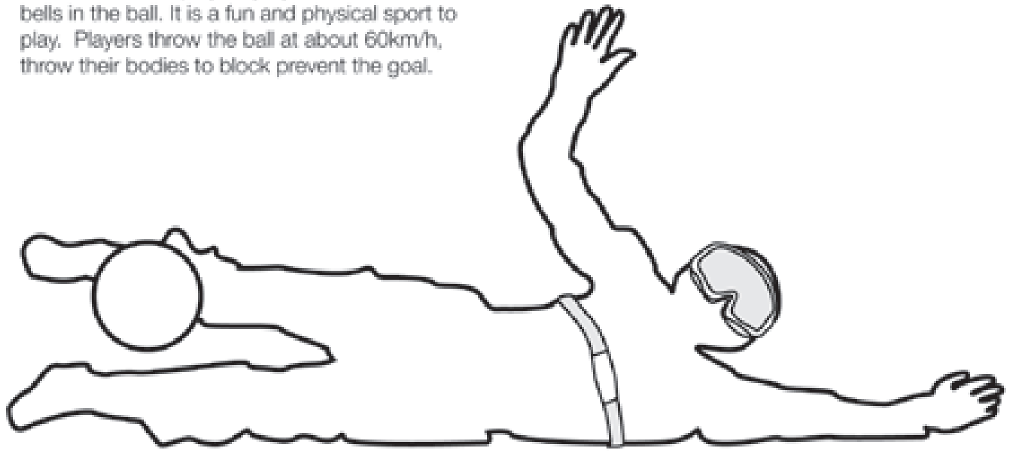
AUGESTRA

YUTA SUGAWARA
TIM BOUCKLEY
JENNY SHIH

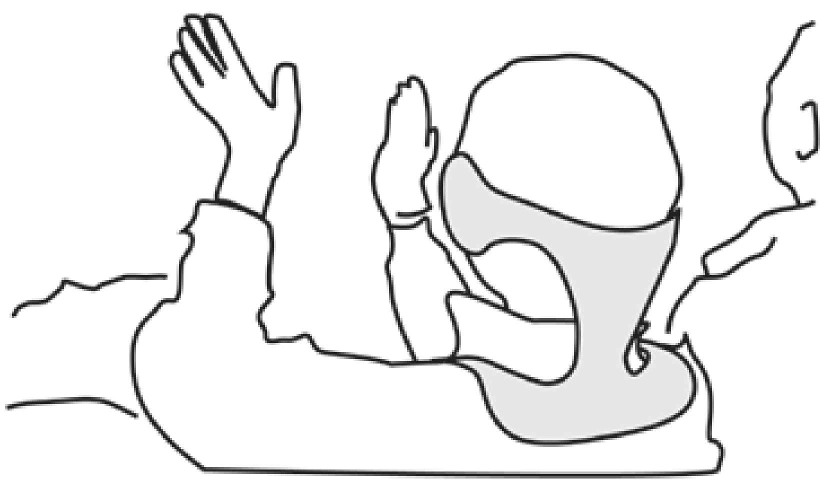
AUGESTRA is an augmented reality device to make the watching of Paralympic sports more exciting by connecting audience members to elite athletes.
The player is equipped with a heart rate monitor and binaural microphones. The player's heartbeat is replicated through a rumbler placed on the chest of the audience device and the binaural audio is heard through stereo speakers in the headset.
The device enhances the audience's experience, giving them the feel of actually participating in the competition as one of the players. Spectators will gain a deeper understanding of the physical achievements of the athletes and a greater appreciation for Paralympic sports in general.



Goalball athletes play only by the sound of the bells in the ball. It is a fun and physical sport to play. Players throw the ball at about 60km/h, throw their bodies to block prevent the goal.



AUGESTRA provides real-time connection and replicates binaural sounds and heartbeats of the player in the pitch. The audience can appreciate the physical achievement of the athletes in the competition.



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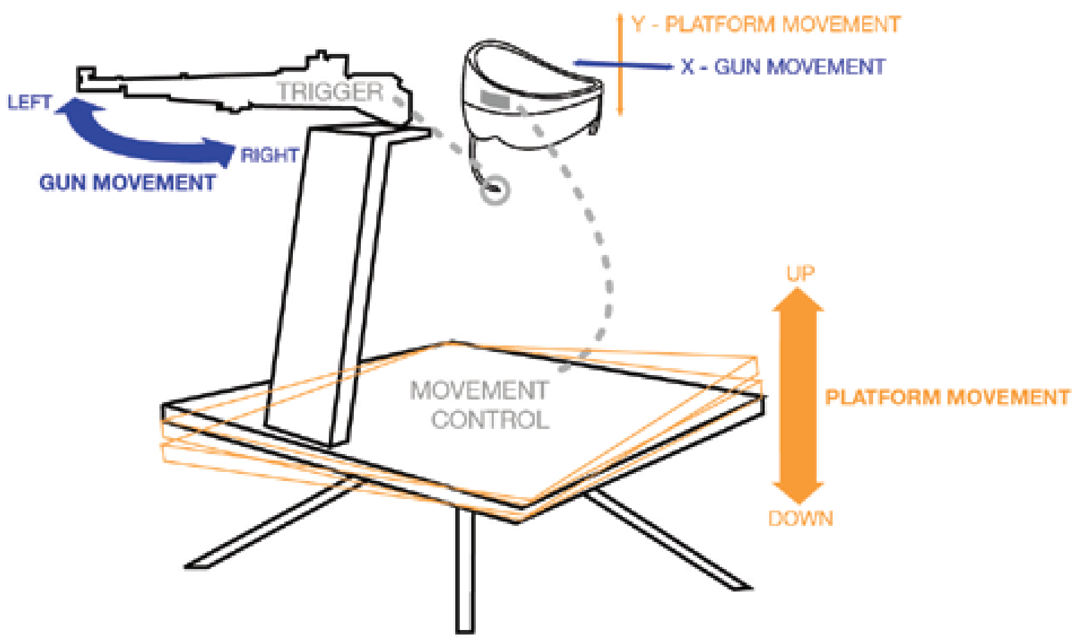
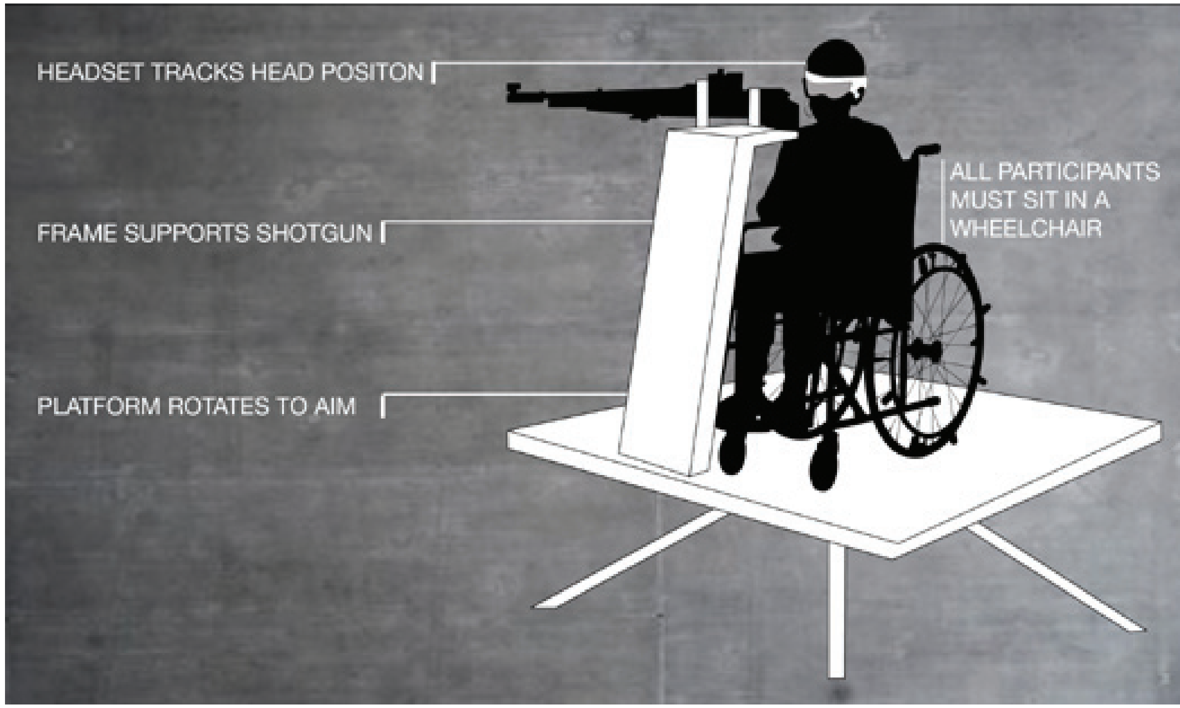
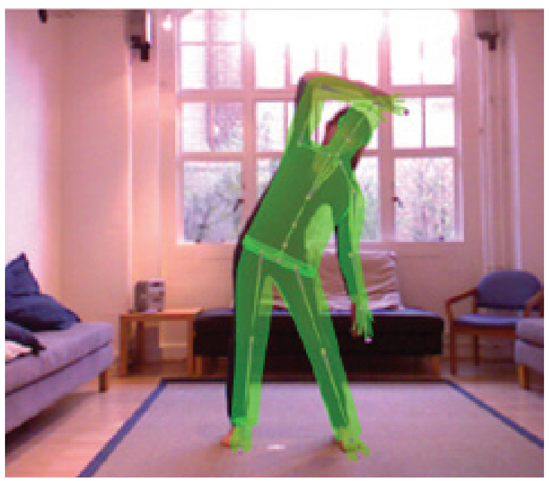
HEAD SHOT

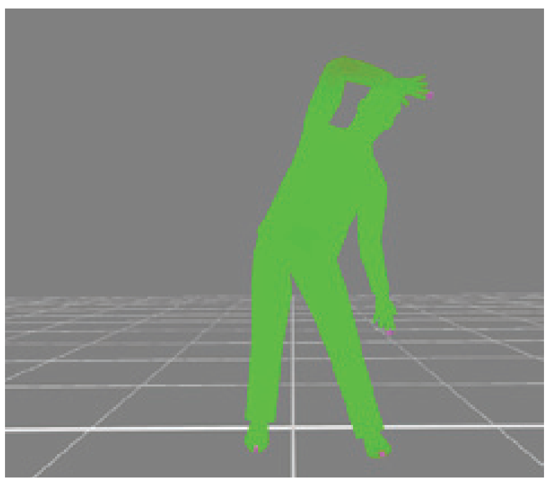
JEFF GOUGH
COLIN MCSWIGGEN
JUHYE LEE

There is a widespread belief that disabled athletes shouldn't compete against able-bodied athletes in the same event. This belief is wrong, and we set out to prove as much by building a no-limbs-required system for one of the oldest modern Olympic sports: clay pigeon shooting. In our system, athletes aim their shotguns by moving only their heads, enabling all people with mobility above the neck to participate on an even playing field. To add an extra challenge and retain the physical dynamism of elite competitive sport, the athlete's entire body moves as he or she aims the shotgun. Take a seat in our working prototype, put on the headset, and try it out for yourself!


Y - PLATFORM MOVEMENT
X - GUN MOVEMENT
TRIGGER
LEFT
RIGHT
GUN MOVEMENT
UP
MOVEMENT CONTROL
PLATFORM MOVEMENT
DOWN


HEADSET TRACKS HEAD POSITON
ALL PARTICIPANTS MUST SIT IN A WHEELCHAIR
FRAME SUPPORTS SHOTGUN
PLATFORM ROTATES TO AIM

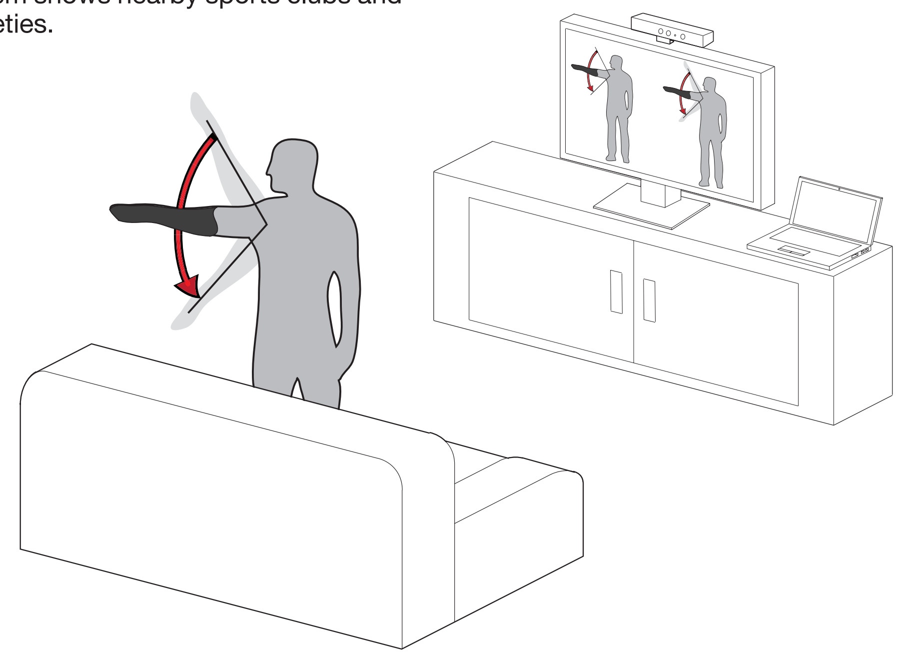




EMPARA

AMA WILLIAMS
JAMES WRIGHT
TANYA CHONG

The Empara system increases inclusion in sport after a trauma disability, with the prospect of producing future Paralympic athletes. It improves health and fitness at home, along with building confidence, with general applicability for all disabilities.
The software comes on discharge after treatment and connects with your home PC and a Microsoft Kinect. With Empara you can improve posture and range of motion, train and exercise, monitor your progress and play sports. The software tracks and captures your motion (ensuring they are carried out correctly). It also allows you to video call your physio/coach to share and exchange exercise routines/goals. When at the sports games stage, the system shows nearby sports clubs and societies.



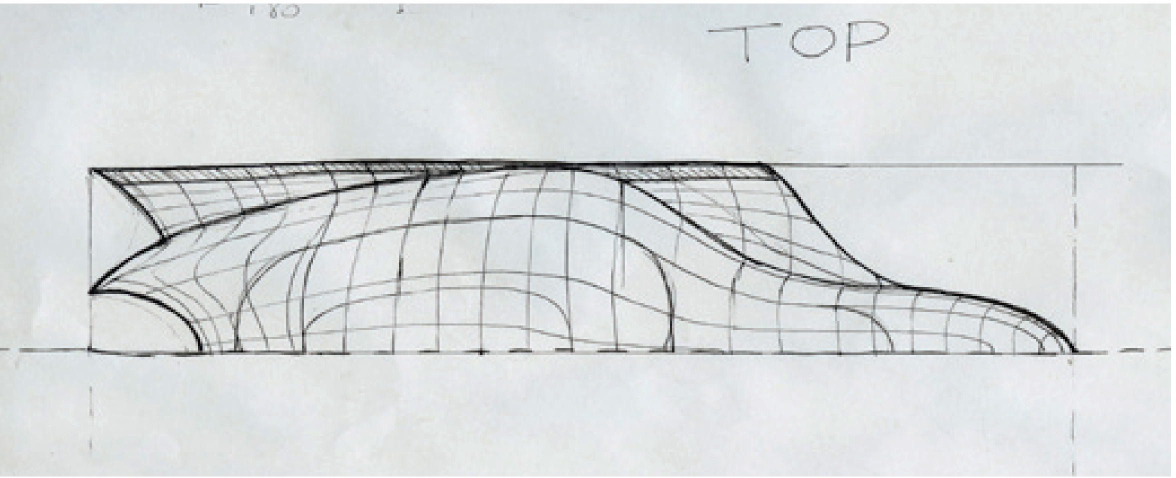
BRAINSLED

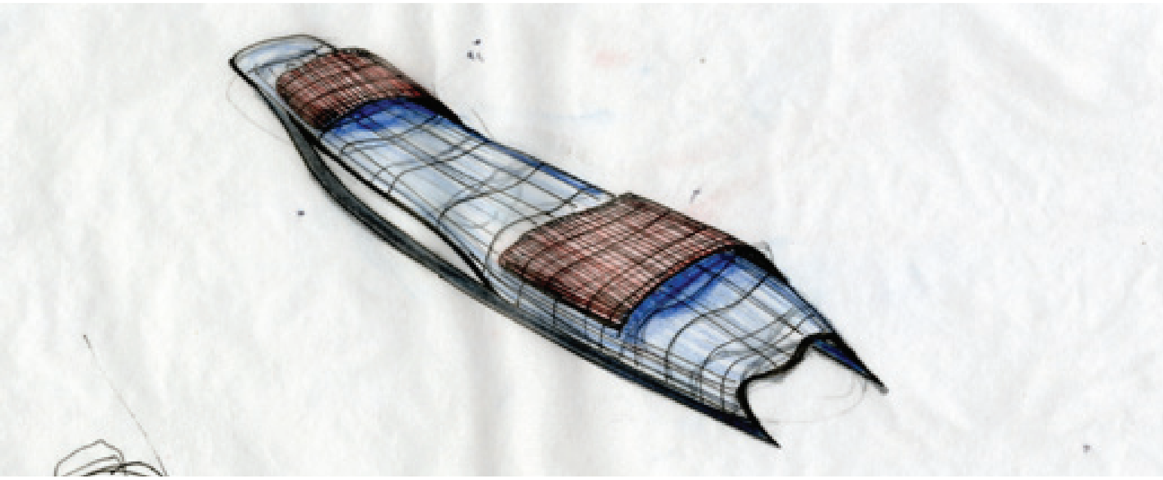
MICHELE TIBERIO
VICTOR MONSERRATE
JAVIER SOTO
SANGWOO PARK

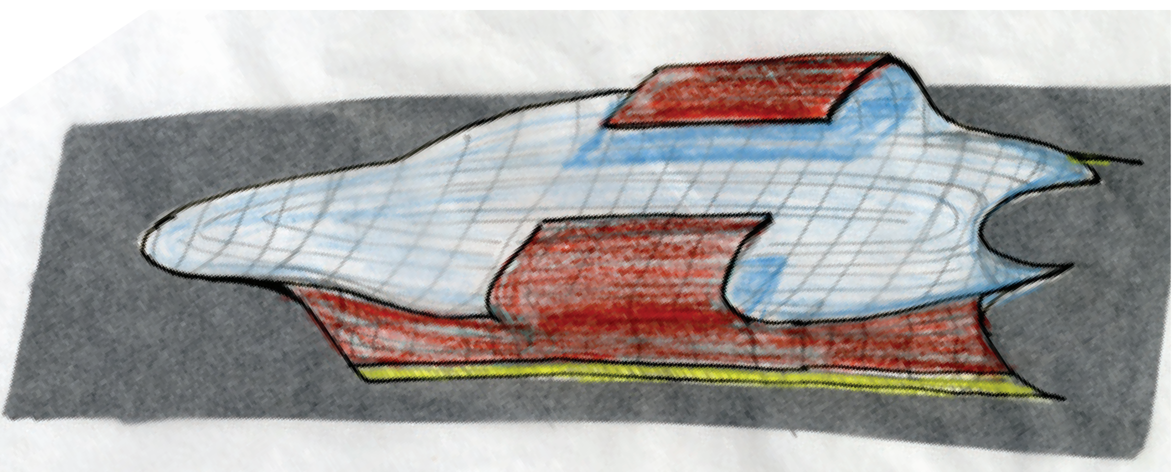
The body is the chariot; the thoughts are the reins and the feelings are the horses

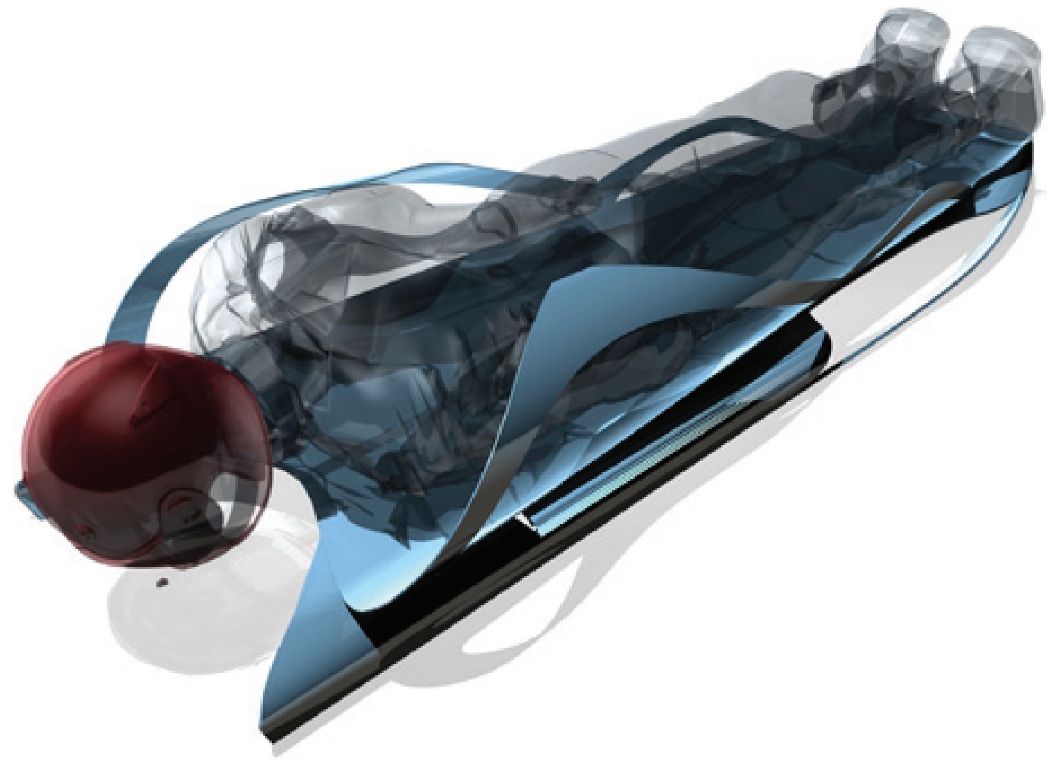
-Plato

Technology keeps on pushing forward human capacities, now there is a way not only to compete in a physical sport in equal conditions, regardless of disability, but also to experience the adrenaline and physical excitement of an extreme activity by people who can currently hardly move from bed.
It is a sport where strength is not a key factor any more, our body will be the sleigh, a device able to travel at 120 kmh, and is directly controlled by the mind.
It will only depend on the brain of the athlete, on its reflexes, on its concentration, on its performance.


TOP







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GHOST

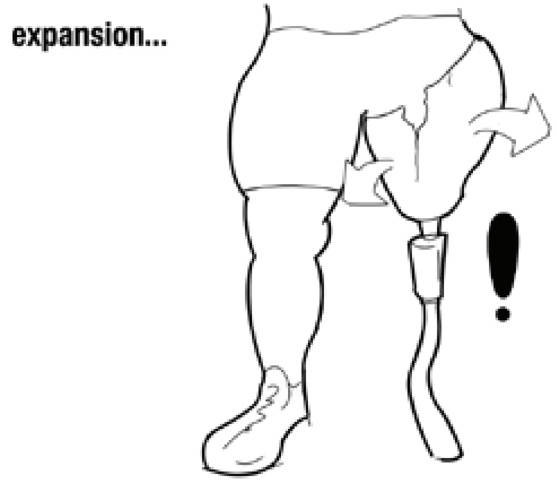
SHRUTI GROVER
BENEDICT COPPING
IDREES RASOULI
JASON CHEAH

In the world of Paralympic swimming, gold medals can be decided by margins as tiny as a fingernail. Swimmers practice to refine and polish their stroke mechanics continuously in order to shave off precious milliseconds from their times.
However, it is vision that allows us to imitate and refine muscular movements , and as such, having a severe visual impairment can make it difficult to correct and perfect these complex motion skills. Athletes depend on physical interaction and auditory feedback from their coach to refine their kinesthetic movements. Our device provides an instant feedback via vibration for constant technique improvement in conjunction with or in the absence of the coach.

ENDURA

MILLIE CLIVE-SMITH
SEBASTIAAN WOLZAK
SEITARO TANIGUCHI

Maximise your sporting performance. Every second counts. During intense physical activity your muscles expand -the unique adjustability of the socket allows you to fine tune the tightness and without needing to slow down.
The ratchet mechanism secures the residual limb ensuring excellent weight distribution.
Train longer. Generated using our Bone Algorithm Technology the open structure allows maximum breathability. Heat and perspiration dissipate quickly meaning training time is not limited by discomfort.
Bone Algorithm Technology, inspired by nature, is applied to the 3D scan of the residual leg to generate a an optimally strong yet open structure.
Wicking technology used in the liner draws moisture away from the skin which is quickly dissipated through the three dimensional structure of the comfort layer.



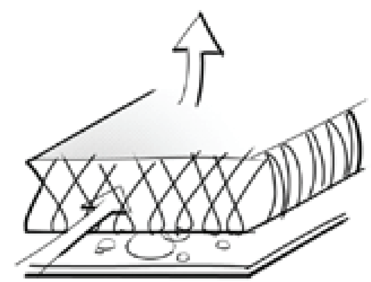
Adjustable Support

A fine tuning tightening mechanism allows you to alter the tightness on the go.

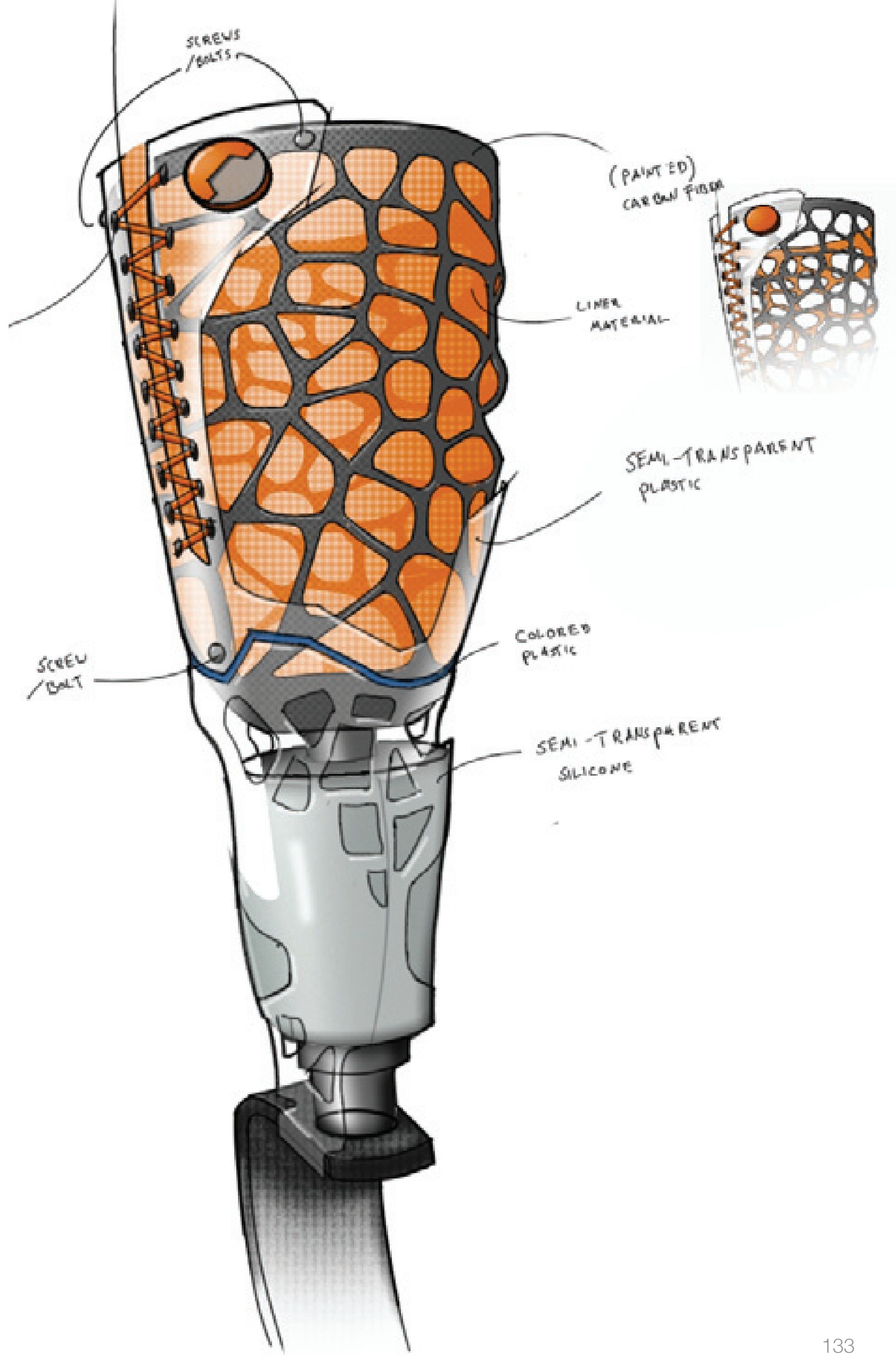
A strong and open structure for maximum support and ventillation.

Inspired by natural bone structure we generated an optimally strong and open structure.

Optimum temperate control



Advanced material structure and properties ensures dissipation of heat and perspiration

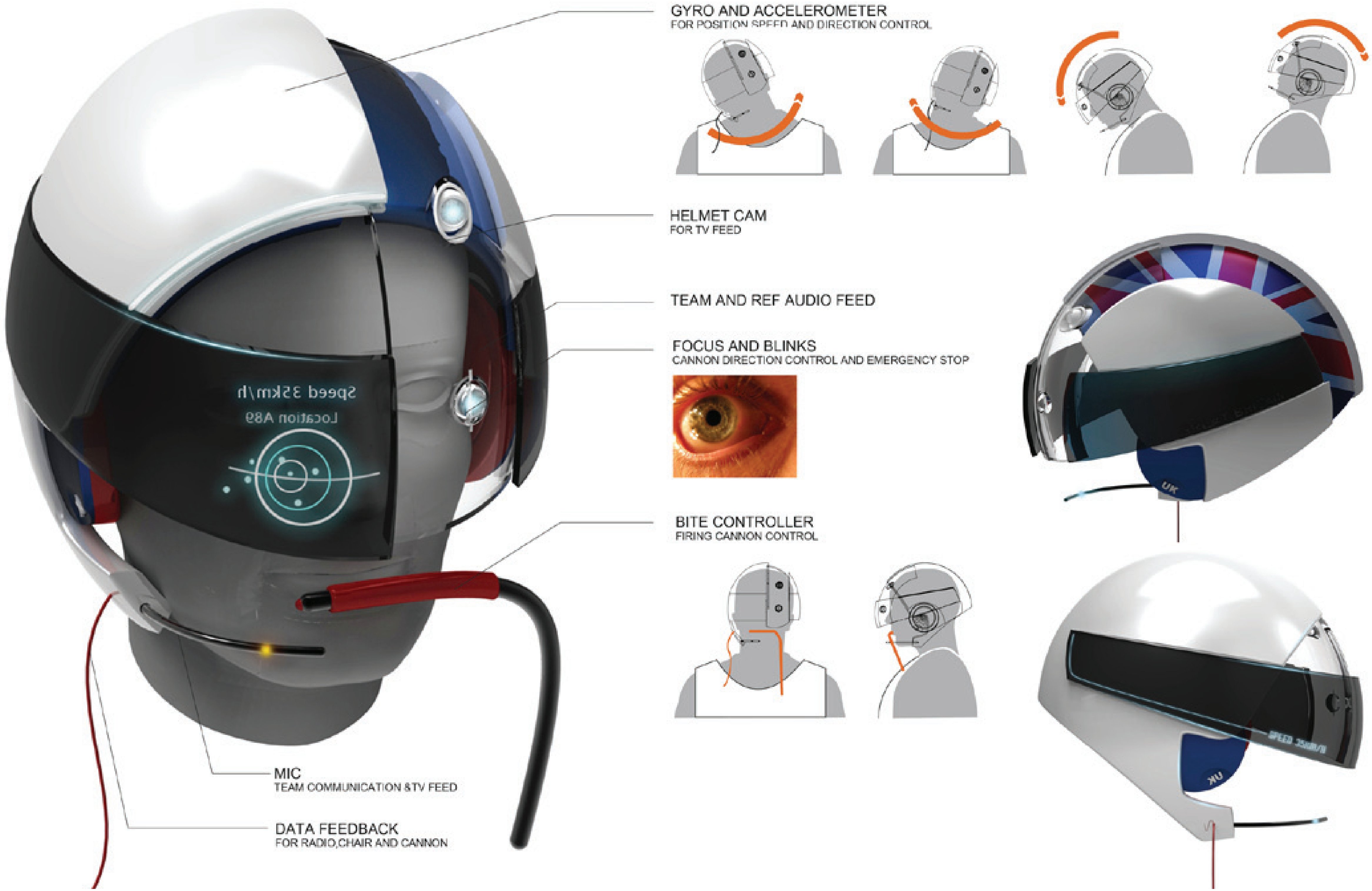


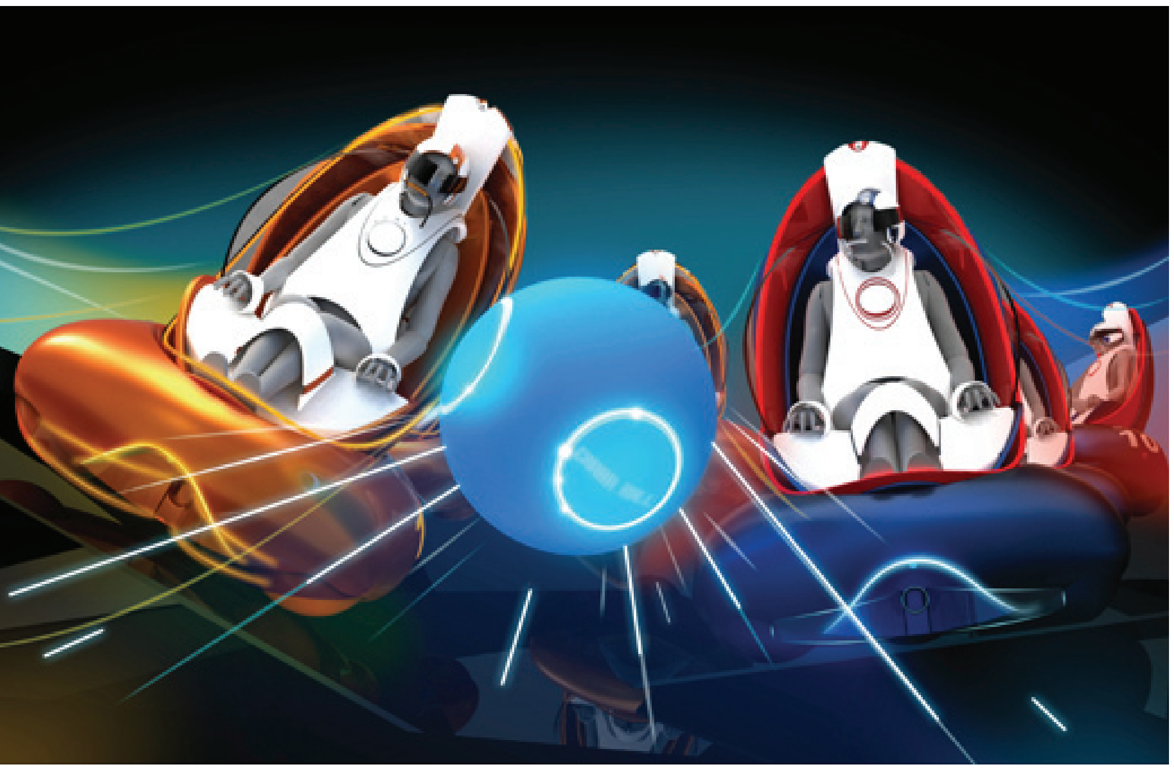
SCREWS /BOLTS
(PAINTED) CARBON FIBER
LINER MATERIAL
SEMI-TRANSPARENT PLASTIC
SCREW /BOLT
COLORED PLASTIC
SEMI-TRANSPARENT SILICONE

CANNONBALL

HUAJUN LONG
ZHANLING FENG
ALAN AMBROSE,
ACKEEM NGWENYA

We present Cannonball - a fast and furious wheelchair team sport where severely disabled athletes control their chairs using an in-helmet accelerometer and bite controller. Cannonball is designed for multiple amputees and high spinal injury athletes and for fast, robust gameplay. Feeds of the players' heads-up display, helmet cams and team audio are provided for a great viewing experience and the ball and chair positions are provided both for live play and TV replay. For training purposes, a team-based virtual version of the game can be played from the athletes' homes using the internet and their standard game helmets.


GYRO AND ACCELEROMETER
FOR POSITION SPEED AND DIRECTION CONTROL
HELMET CAM
FOR TV FEED
TEAM AND REF AUDIO FEED
FOCUS AND BLINKS
CANNON DIRECTION CONTROL AND EMERGENCY STOP
BITE CONTROLLER
FIRING CANNON CONTROL
MIC
TEAM COMMUNICATION &TV FEED
DATA FEEDBACK
FOR RADIO,CHAIR AND CANNON
UK
UK




GREAT BRITAIN
1.0

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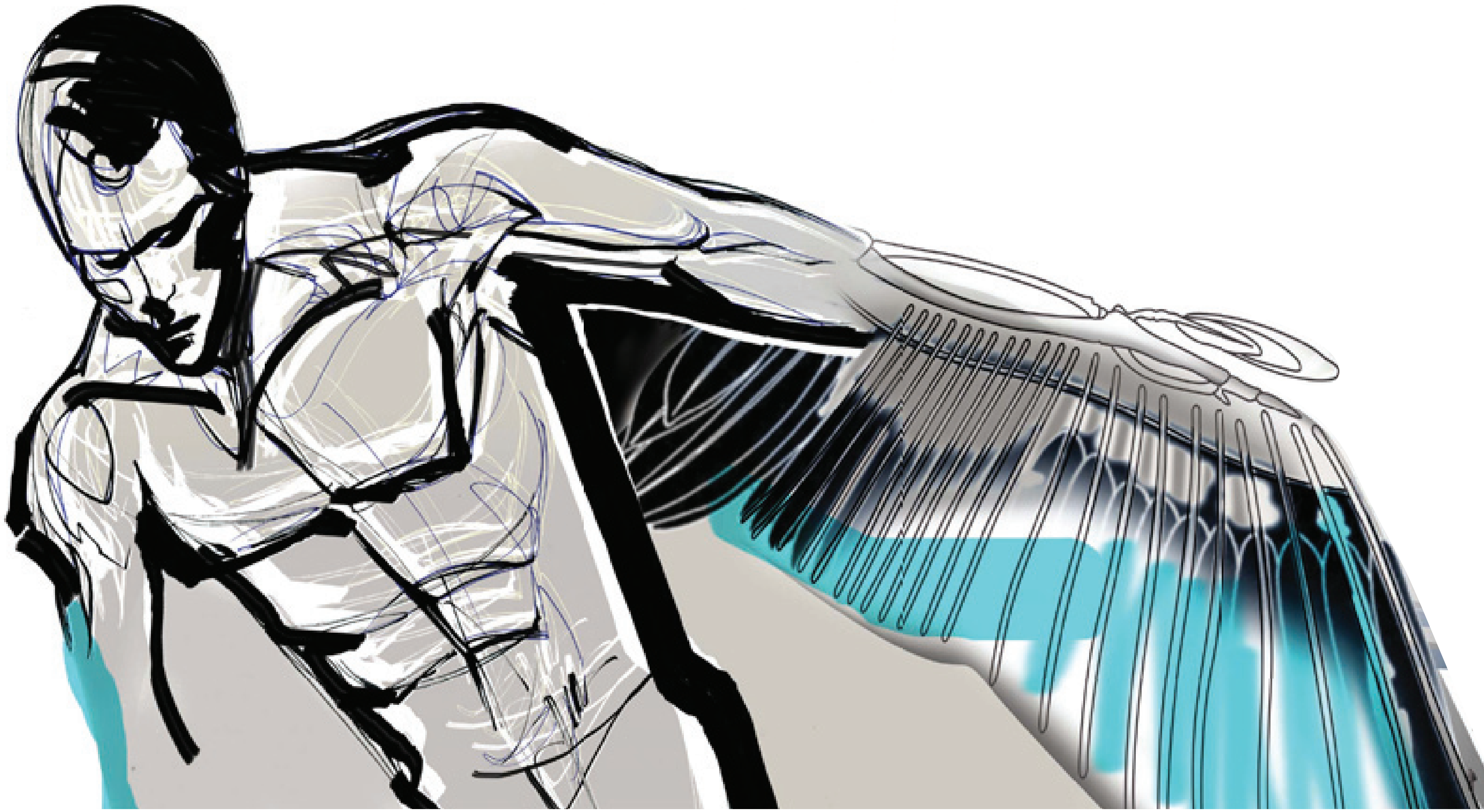
AVIAN SPORT

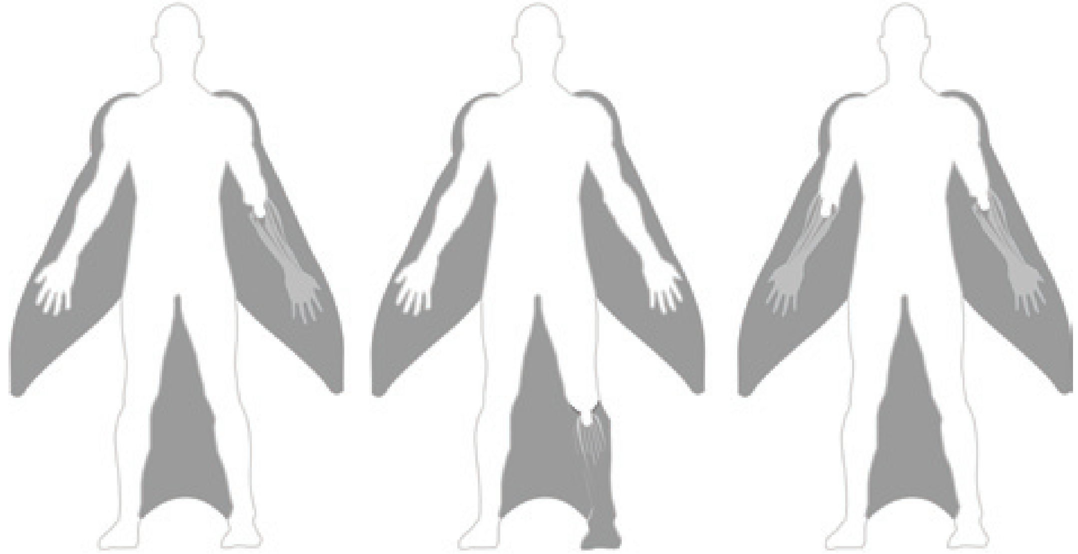
NAYOUNG KIM
TING-HAN CHEN
JOHNATHYN OWENS

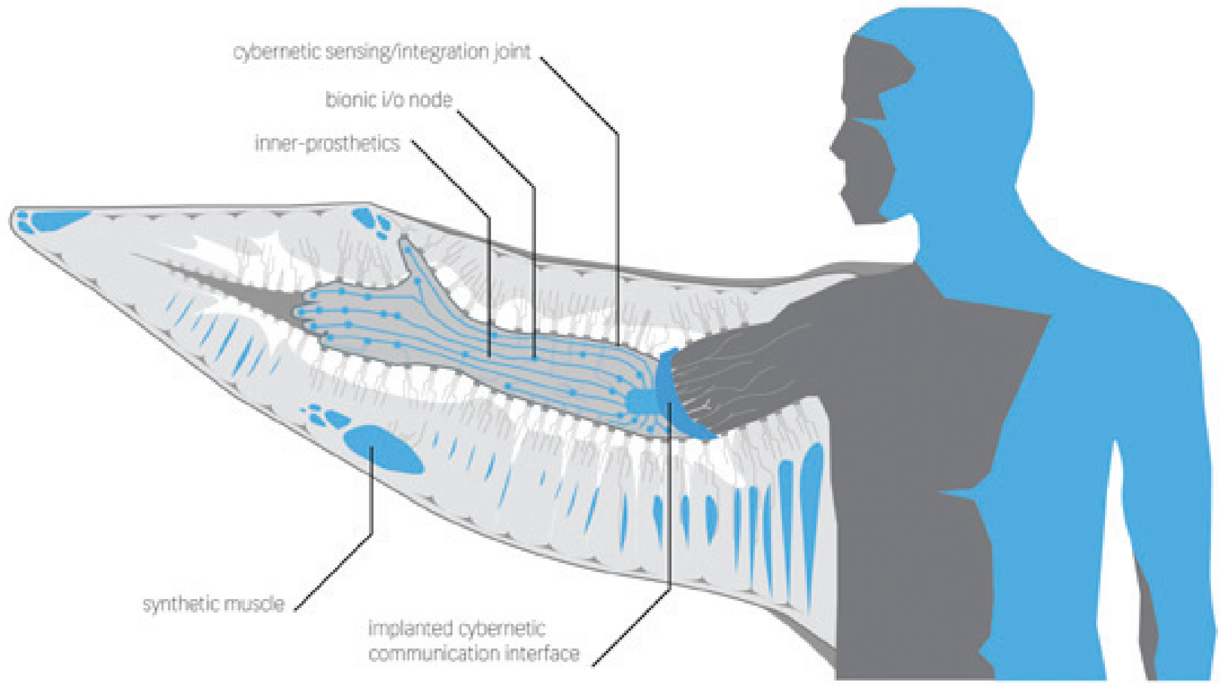
We set out to introduce a new sport for the Paralympic games 2056 incorporating future technology, that shifts the view of the Paralympics away from an Olympics for the disabled and to an Olympic event of the uniquely-abled, and that gives athletes grace, satisfaction of achievement, and self confidence, by enhancing them in a way that only they can use.

A prosthetic limb doesn t represent the need to replace loss anymore. It can stand as a symbol that the wearer, has the power to create whatever it is they want to create in that space. So people that society once considered to be disabled, can now become the architects of their own identities, and continue to change those identities, and continue to change those identities by designing their bodies from a place of empowerment.

-Amee Mullins 2009






cybernetic sensing/integration joint
bionic i/o node
inner-prosthetics
synthetic muscle
implanted cybernetic communication interface

MIND SURFER

HANKAK LEE
PETER CODLING
ROSHAN SIROHIA

2056 - A new era is coming. At the dawn of the Technological Singularity, the megacity of Abu Dhabi has expanded far and wide, incorporating cutting edge design and technology systems from around the world with increasing temperatures and more sand around to play with.

Host to the 2056 Paralympic Games it marks the beginning of nanotechnology revolutionizing sport for the Super-abled athletes in the arena of Mind Controlled Sand Surfing. The race requires the surfers to imagine the wave, which the self replicating nanobots create, while being attracted to the board - thus creating the force to push the wave around a dynamic swirling race track.

Figure 56: IDE student Johnathyn Owens tries out Jimmy Goddard's racing wheelchair

VIGNETTES

"We want to get out, experience some challenges and have some fun like everyone else. We ve already had our accidents and so we don t have much fear.

Jimmy Goddard

It has been a pleasure working with you and with all the tutors (10 or more...) and the resource of this module.
Crazy project in order of time and deliverable but extremely exciting and enjoyable, moreover big thanks to all the IDEers.
The exchanges and discussions we had between us have been a key factor for the result of this project. I really enjoyed working with the big variety of backgrounds and knowledge.
Ciao.

Michele Tiberio

The Rio Tinto Sports Innovation Challenge was a new project that made us take everything we knew, know, and thought we knew about sport and push it to the limit. Then we pushed some more. It was imaginative and inspiring, and some of the most fun work I have done in my career.

Johnathyn Owens

Figure 57: Baroness Tanni Grey-Thompson giving her keynote talk at Imperial College London

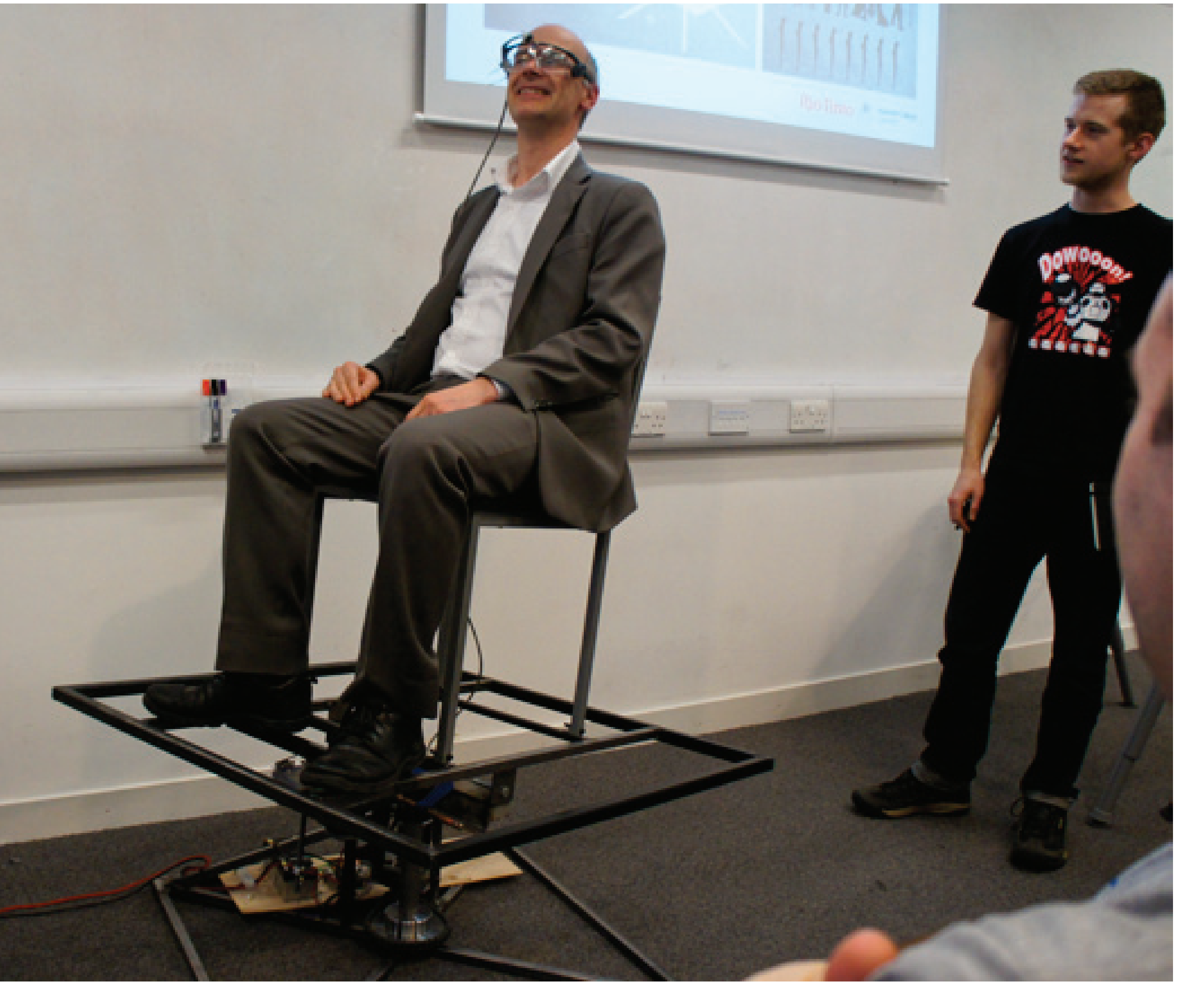


Figure 58: Prof. Peter Childs tests the head-controlled platform for inclusive clay-pigeon shooting

ACKNOWLEDGEMENTS AND THANK YOU

David Keech for leading the module
Matt Kavanagh for assisting on the lead
Rolf Thomas, Julian Hall, Andy Brand, Becky Pilditch, Peter Kuschnigg and Damon Miller for tutoring
Igor Safranov and Javier Soto for photographing the module
Isabel Lizardi for graphic design
Dominic Southgate for Rio Tinto liaison
IMG for running the public facing events
Jimmy Goddard, Scott Moorhouse, James Smith and Iain Dawson for expert athlete input
Epson for providing projection facilities
Synapse for model making
Baroness Grey-Thompson of Eaglescliffe in the County of Durham for her keynote
Ashley Hall for supporting the module at the planning phase
Gordon Addy and Ingrid Logan for support from the IDEAs Lab
Peter Kuschnigg for show curation
Greg Sharp, Sports Development Manager at the University of Bath for facilitating a Paralympic sport performer day visit
Otto Bock healthcare products GmbH for permission to use photographs

...and lastly

Rio Tinto for sponsoring the Rio Tinto Sports Innovation Challenge activities at Imperial College London

Figure 59: Jimmy Goddard demonstrates the features of his racing wheelchair at an athlete workshop