Sports Tech Research Centre

PART OF MID SWEDEN UNIVERSITY

3D-printing: a future "magic wand" for global manufacturing. How can we benefit from it today for sports and health care?

Andrey Koptyug, Mikael Bäckström, Lars-Erik Rännar

Sports Tech Research Centre, Mid Sweden University, Östersund, Sweden
{andrei.koptioug, mikael.backstrom, lars-erik.rannar}@miun.se

icSPORTS 2017

5th International Congress on Sport Sciences Research and Technology Support

Funchal, Madeira - Portugal · 30 - 31 October, 2017

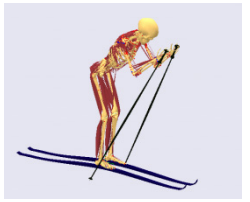
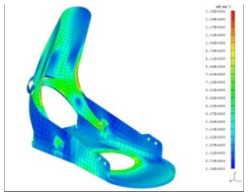
OUTLINE OF THE TALK

- *Who we are*
- *What is 3D printing*
- *Common perception of 3Dp*
- *Place of 3Dp related to other technologies*
- *How it works in a nutshell: polymers, metal*

Some 3Dp applications

- *for general technology*
- *for sports technology*
- *for injury prevention*
- *for injury treatment*
- *for para-sport*

- *Summary and Conclusions*

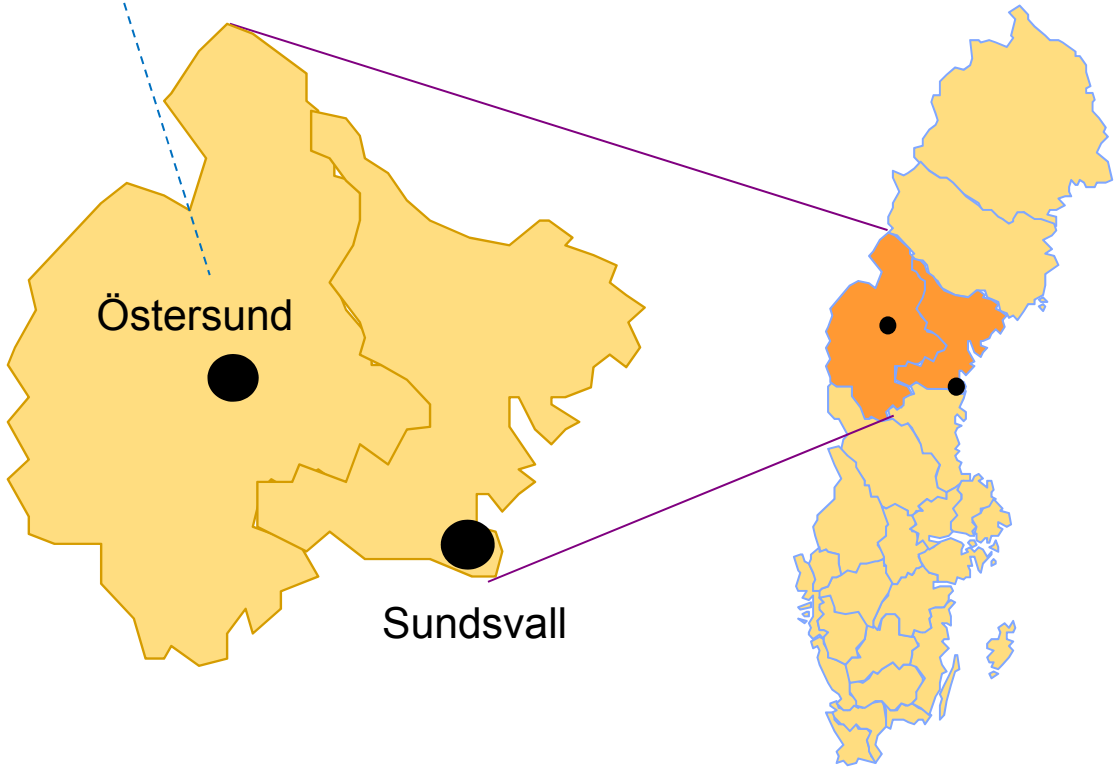




WHO WE ARE

Sports Tech Research Centre
Mid Sweden University

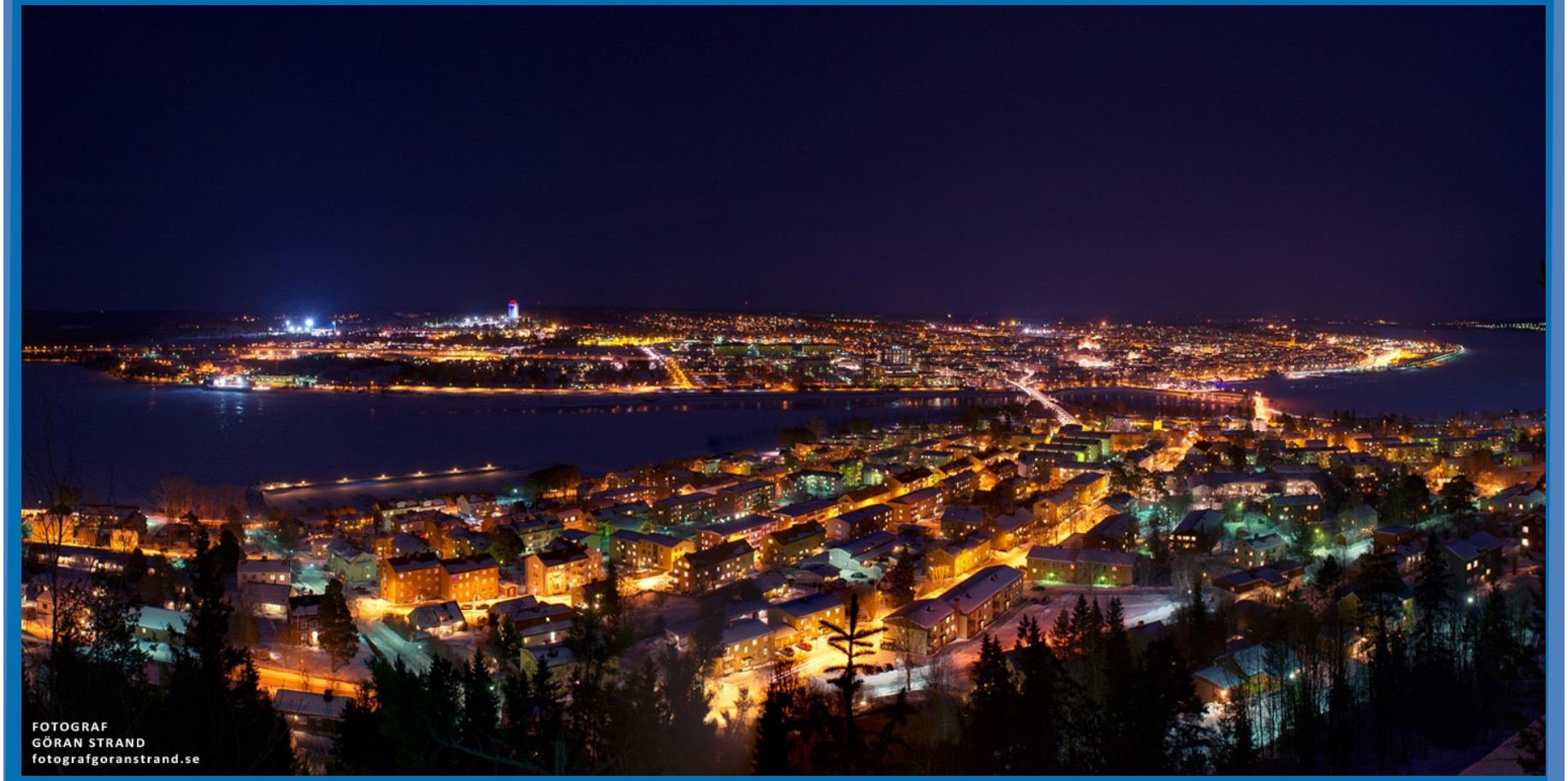
Sports Tech Research Centre
PART OF MID SWEDEN UNIVERSITY

Mittuniversitetet
MID SWEDEN UNIVERSITY



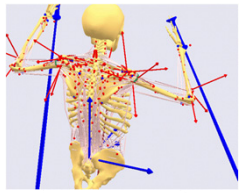
City of Östersund

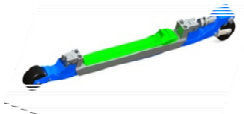
600 km north from Stockholm, County of Jamtland, about 37,000 people

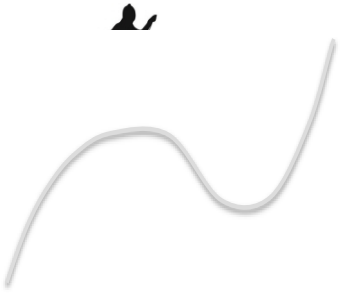


Sports Tech Research Centre

PART OF MID SWEDEN UNIVERSITY







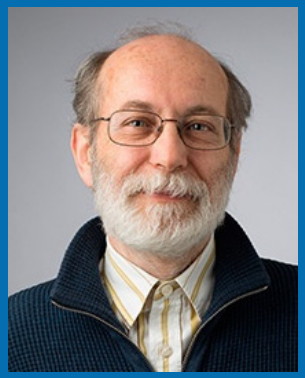
Biomechanics and performance optimization

Human and equipment interaction

Additive manufacturing and materials

AM group at Sports Tech

MIUN.SE
DISCOVER YOUR OPPORTUNITIES



Assoc. Prof.
Andrey Koptyug

Assoc. Prof.
Lars-Erik Rännar

Prof.
Mikael Bäckström

Lic. , PhD student
Rebecca Klingvall

Engineer
Per Scoglund

PhD student
Stefan Roos

Dr.
Marie Cronskär

Actively using AM technology; AM in metal- since 2000

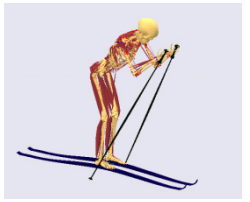
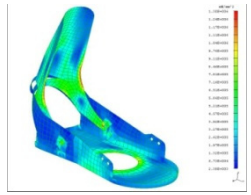
icSPORTS 2017
5th International Congress on Sport Sciences Research and Technology Support

Funchal, Madeira, Portugal, 30-31 October, 2017

Sports Tech
Research Centre

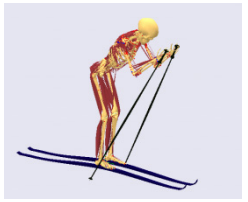
WHAT DO PEOPLE KNOW OF 3D PRINTING

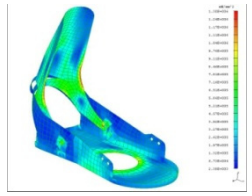
Is there anyone here
who does not know anything
about 3D printing?


WHAT DO WE KNOW OF 3D PRINTING

Point of view: Economist





WHAT DO WE KNOW OF 3D PRINTING

Point of view: Cartoonist

CGI 3D Animated Short HD: "Print Your Guy"

WHAT DO WE KNOW OF 3D PRINTING

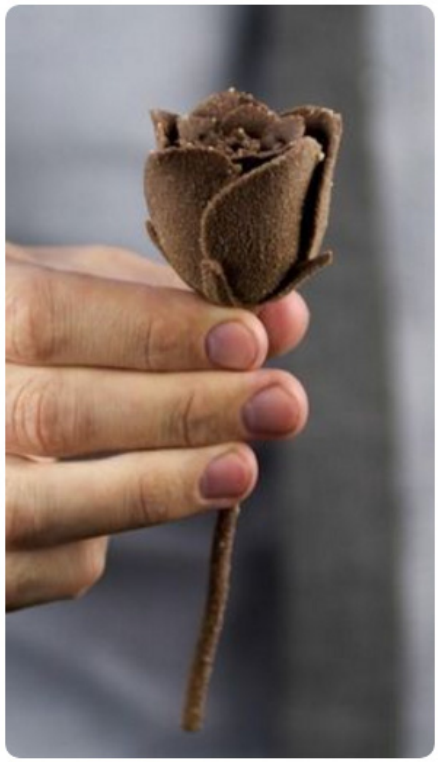
Point of view: Olaf Diegel ***Professor, Lund University, Sweden***

http://www.product.lth.se/staff/olaf-diegel

WHAT DO WE KNOW OF 3D PRINTING

Point of view: Food lovers

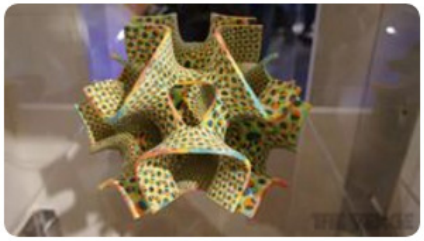
3D-printed gummies are real and you can eat them



3D Systems Unveils CocoJet Chocolate 3D Printer At 2015 CES

http://www.3ders.org/

3-D Printed Candy Makes Me Love The Future



Eating delicious 3D candy printed by a ChefJet

WHAT DO WE KNOW OF 3D PRINTING

Point of view:
clothes & shoes
designer

3dprint.com

These 3D Printed Carbon Fiber Shoes are an Engineering "Feet"

A 3-D PRINTED DRESS THAT'S ALMOST PRACTICAL ENOUGH TO WEAR

https://www.wired.com/2016/03/3-d-printed-dress-thats-almost-practical-enough-wear/#slide-1

WHAT DO WE KNOW OF 3D PRINTING

Construction business

https://www.engadget.com/2017/03/07/apis-cor-3d-printed-house/

San Francisco-based startup Apis Cor built a whole house in a Russian town within 24 hours.

WHAT DO WE KNOW OF 3D PRINTING

Bio science: body parts and tissues

nature International weekly journal of science

NATURE | NEWS 15 April 2015

The printed organs coming to a body near you

Frank Wojciechowski

The increasing sophistication of 3D printing is shown in an ear that melds biological and electronic parts.

POSSIBILITIES

And many more possibilities already exist

Actually, there are!

It looks that there are no limits!

And though, these limits are 'high in the sky'

we need to know them!

I HAVE NEWS FOR YOU

MIUN.SE
DISCOVER YOUR OPPORTUNITIES

All mentioned technologies

strictly speaking

ARE NOT PRINTING!

So I shall use the term

Additive Manufacturing

(AM)

AM MACHINES AT SPORTS TECH

Fused deposition modeling (FDM)- polymers

stratasys

MakerBot

Powder-bed fusion: metals and alloys

A2 EBM® machine by ARCAM

www.arcam.com

Universal test platform

Objet Eden

stratasys

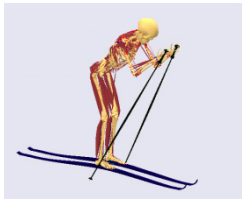
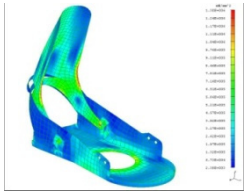
Bubble-jet printer (polymers)

ADDITIVE MANUFACTURING

Adding material layer by layer:

We are getting an unprecedented possibility to design components of extremely complex shapes,
and to manufacture them
in a single technological process

in a single technological process

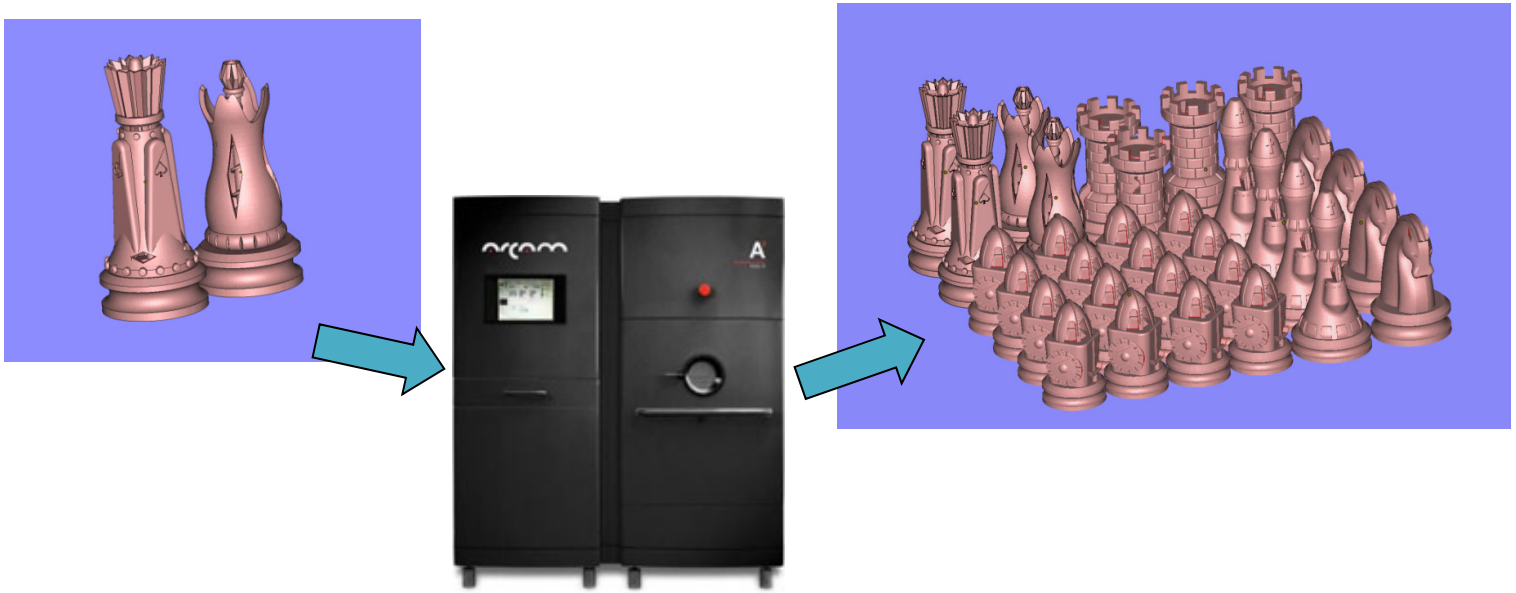




ADVANTAGES OF AM

MIUN.SE
DISCOVER YOUR OPPORTUNITIES

Extra advantages:

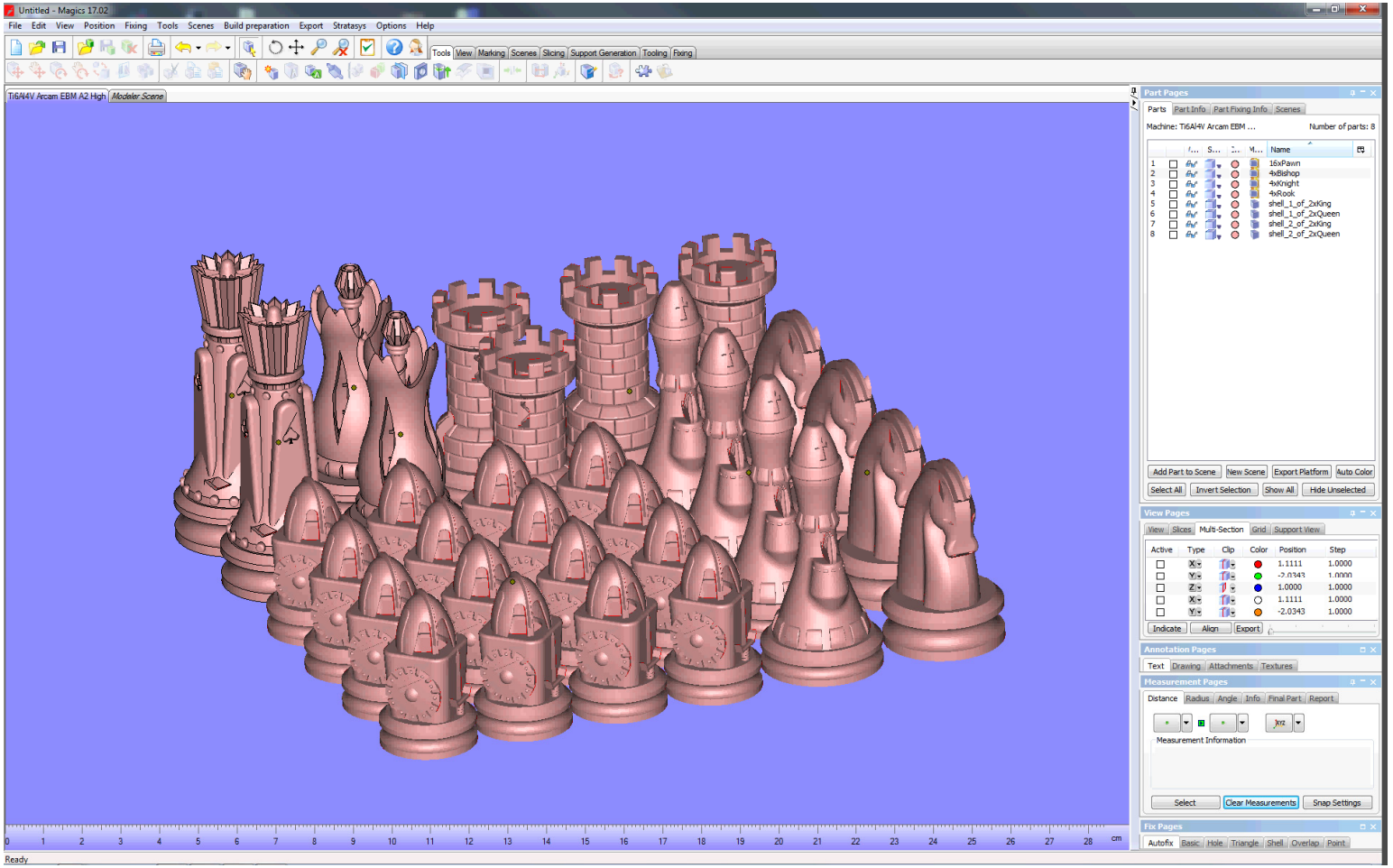
- the method produces minimal materiel waste
- the lead time to product is short
- ”impossible” geomeries are possible

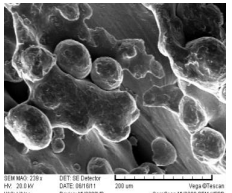


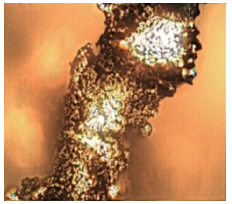
AM machine is ”a link between 3D virtual reality and real world”

AM: LAYER- BY- LAYER

MIUN.SE
DISCOVER YOUR OPPORTUNITIES

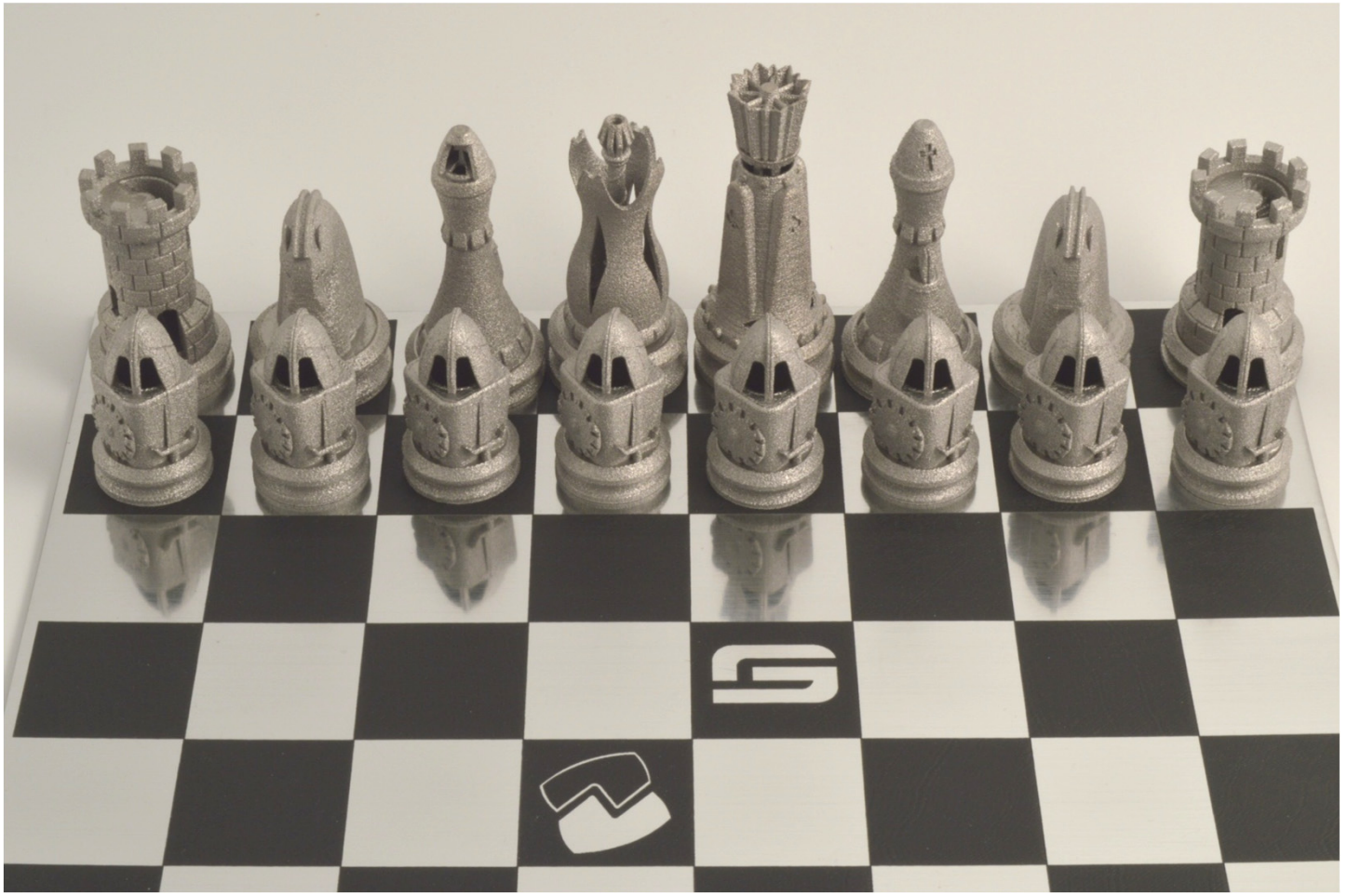






Result of manufacturing

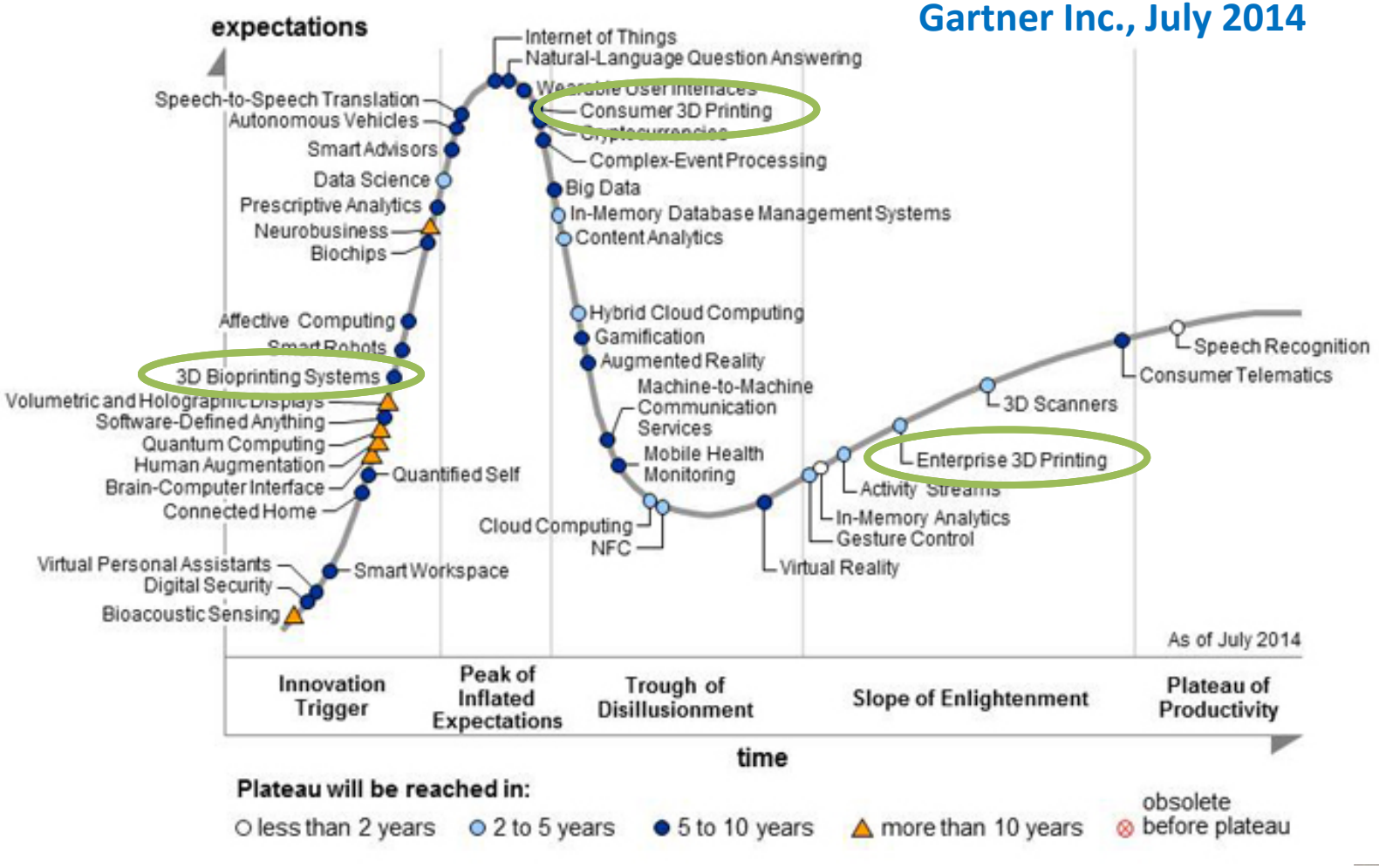
MIUN.SE
DISCOVER YOUR OPPORTUNITIES



AM IN REAL WORLD

MIUN.SE
DISCOVER YOUR OPPORTUNITIES

Gartner Inc., July 2014



AM: EFFICIENCY

MIUN.SE
DISCOVER YOUR OPPORTUNITIES

Time spent
Energy used
Material waste

Costs

Manufacturing costs
Vs
Component complexity

Traditional manufacturing

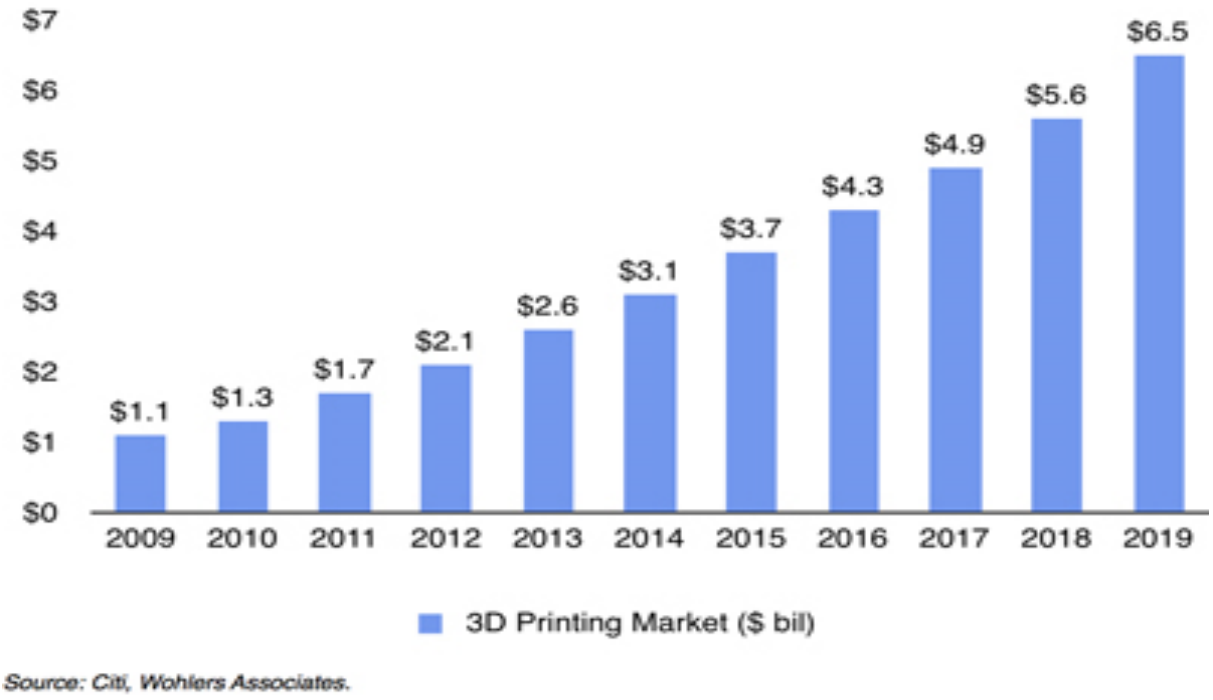
Additive manufacturing

AM: lightweight structures

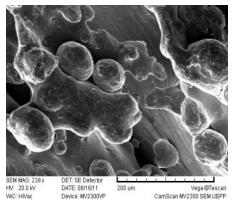
small *medium* *extreme*

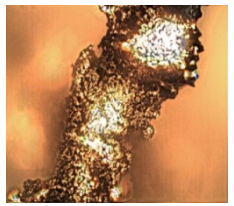
Complexity

FUTURE MARKET



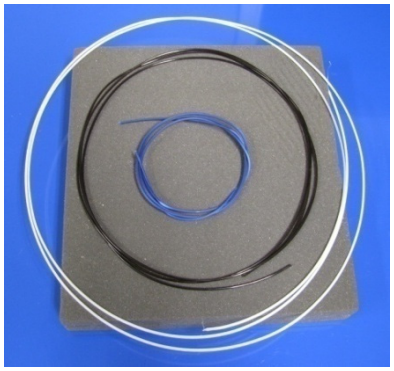
Source: Citi, Wohlers Associates.

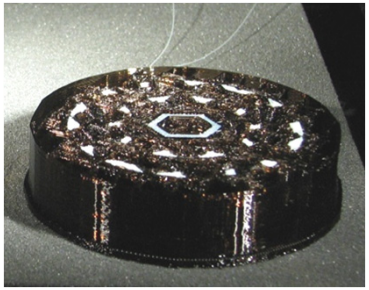


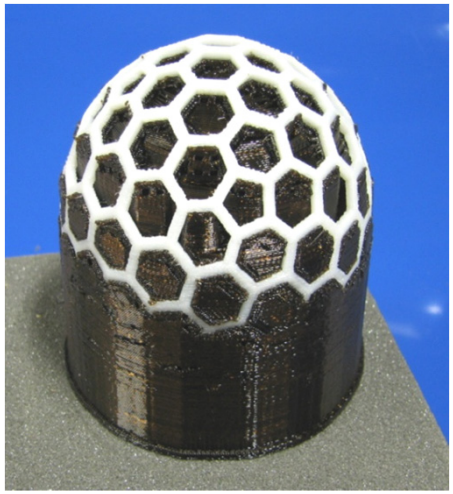


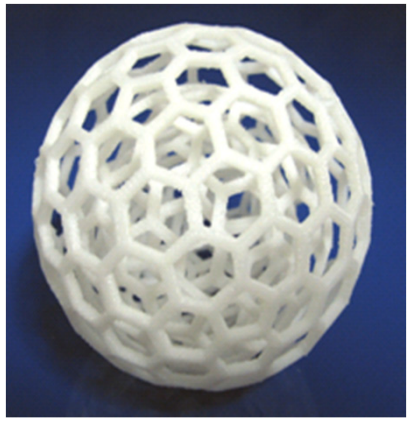
According to **Wohlers Associates** and **Citigroup** (2014), the 3-D printing market could grow to $6.5 billion by 2019 from less than $3.5 billion today.
The aerospace, orthopedic, and other high value, low volume industries will be the earliest adopters

AM IN POLYMERS: FDM

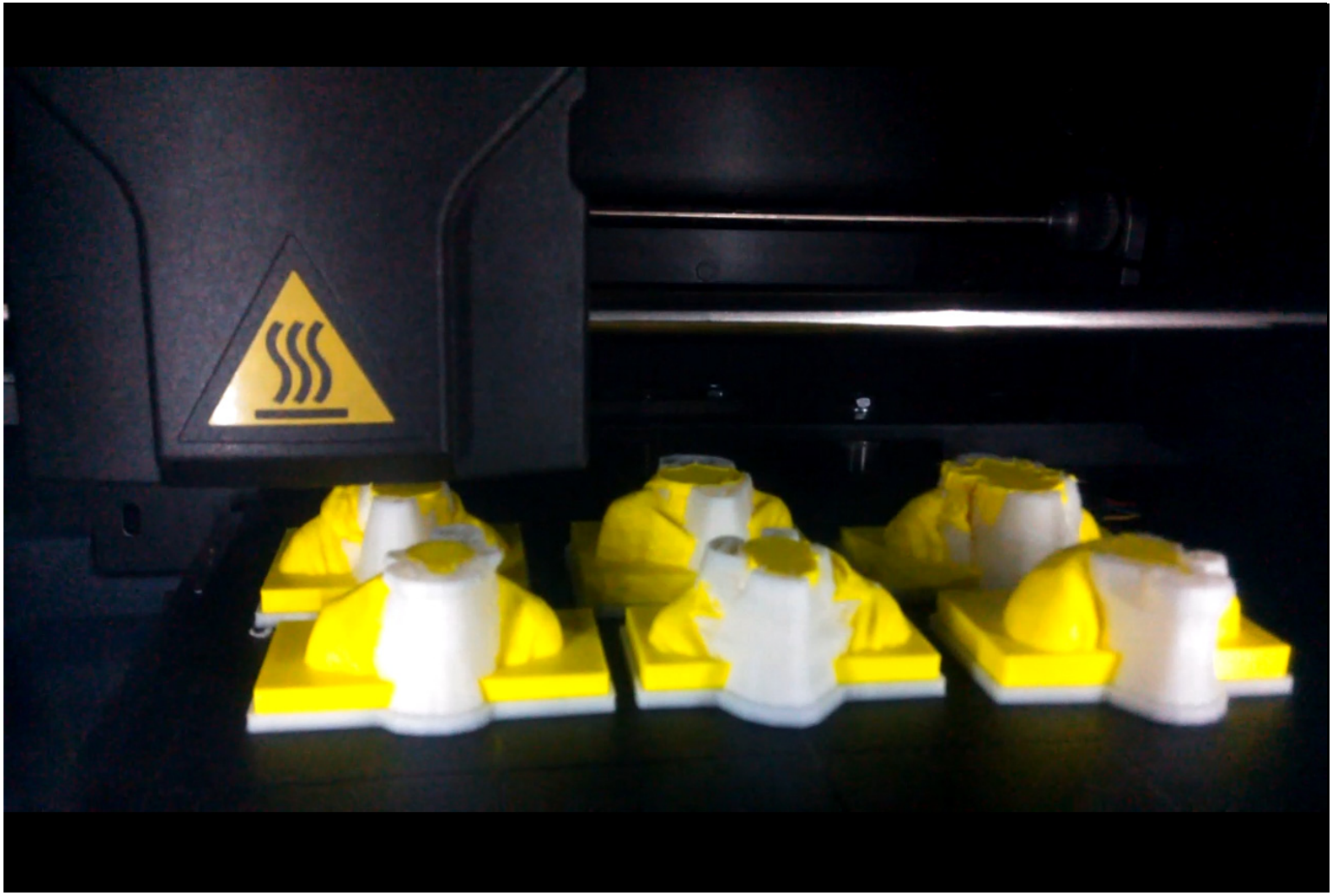








FDM IN ACTION

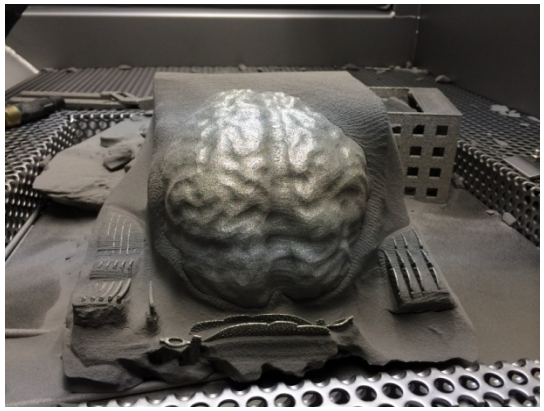


AM IN METAL: EBM = POWDER BED PROCESS

Inside vacuum chamber

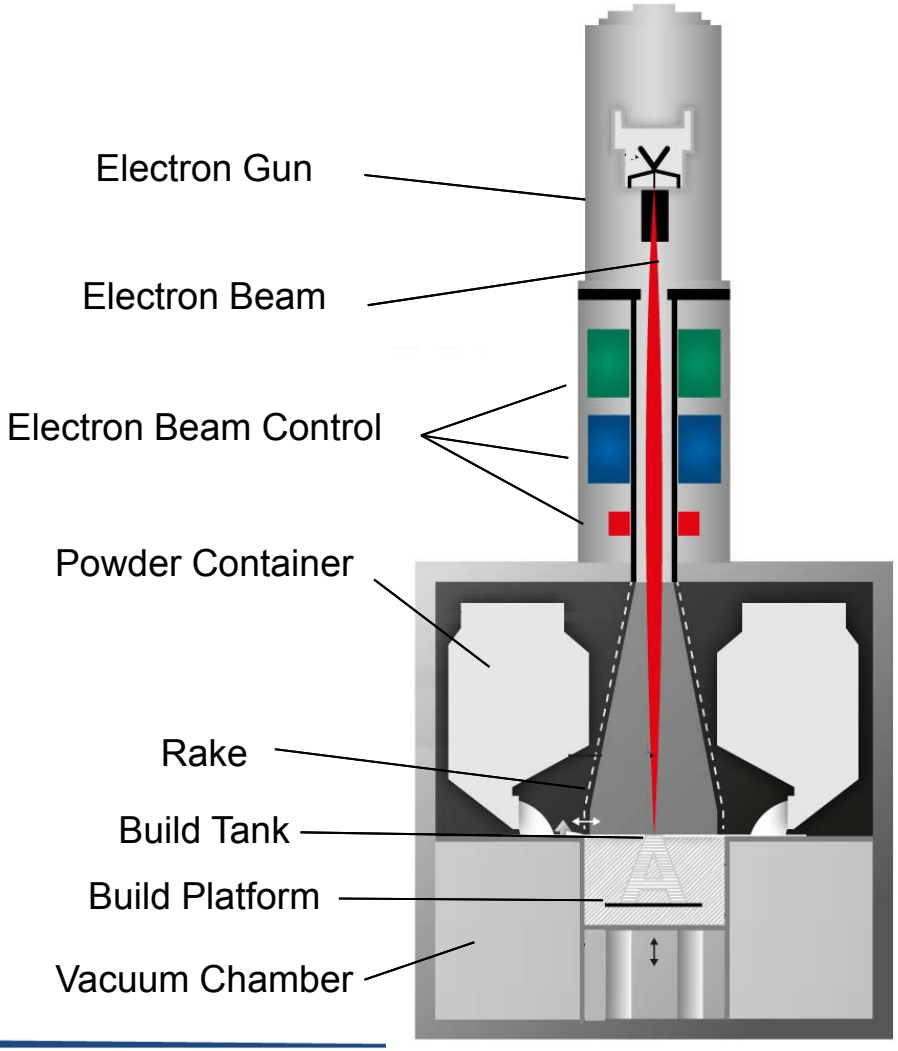
Powder Recovery System

Components inside sintered powder



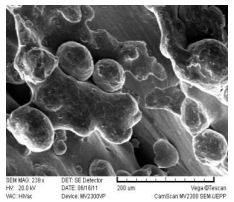
ELECTRON BEAM MELTING

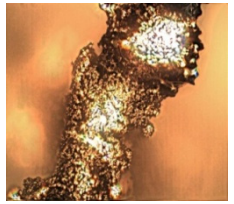
A2X EBM® machine



EBM: THROUGH INSPECTION WINDOW

MIUN.SE
DISCOVER YOUR OPPORTUNITIES

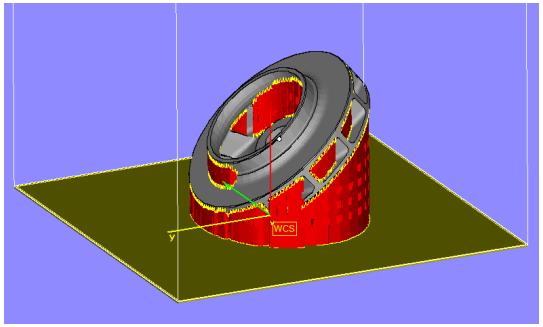




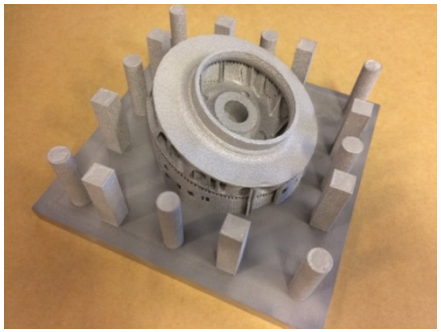
ADVANTAGES FOR TECHNOLOGY

MIUN.SE
DISCOVER YOUR OPPORTUNITIES

Complex shapes- in a single technological process

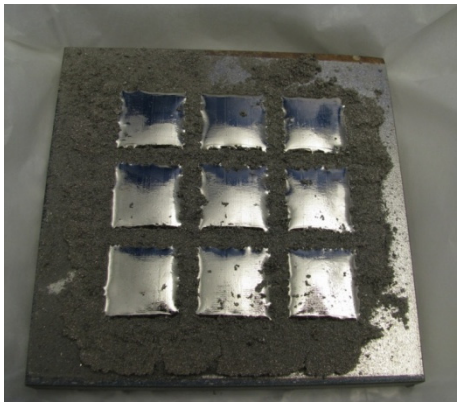


316L stainless steel



exmet

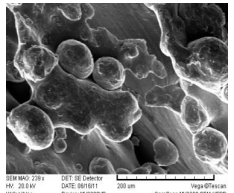
Amorphous steel (BMG)

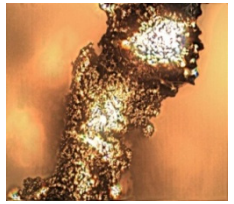


Unique new materials

VBN COMPONENTS

High C tooling steel

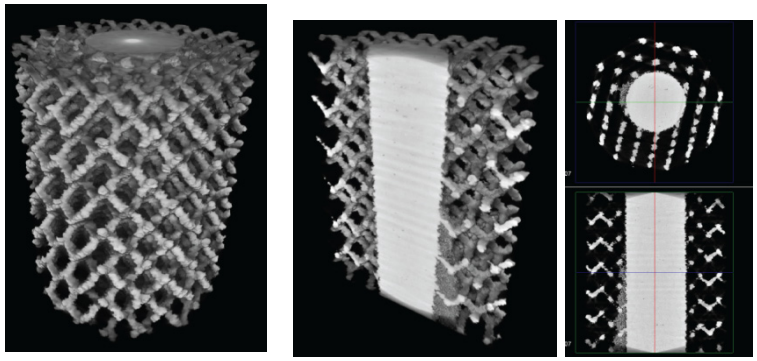




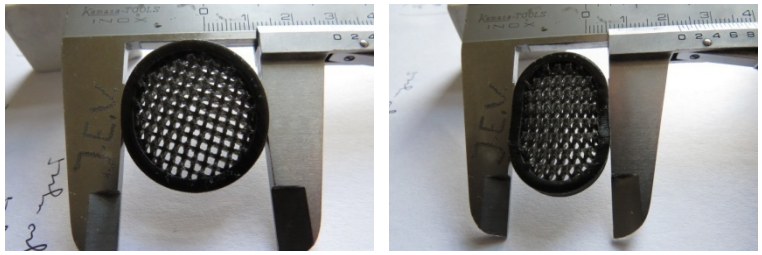
ADVANTAGES FOR TECHNOLOGY

MIUN.SE
DISCOVER YOUR OPPORTUNITIES

Complex and lightweight structures



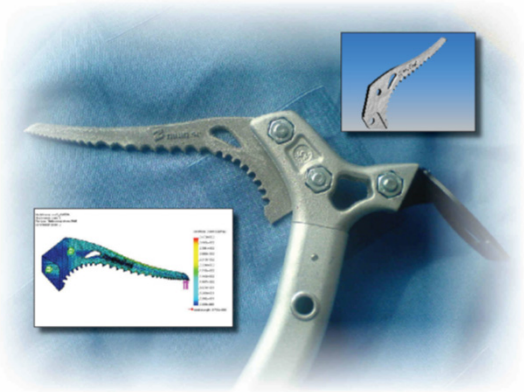
Ti and Ti64



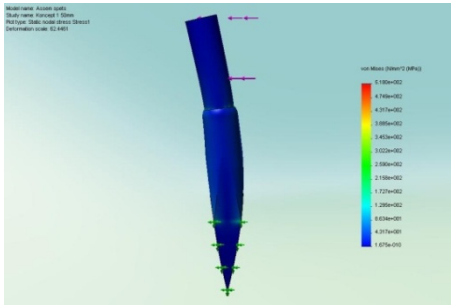
Hard and soft polymers

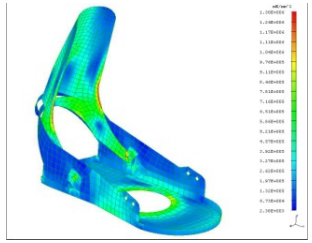
AM FOR SPORTS TECHNOLOGY

Prototyping



Ice ax blade in CoCr





Ergonomic ski pole grip

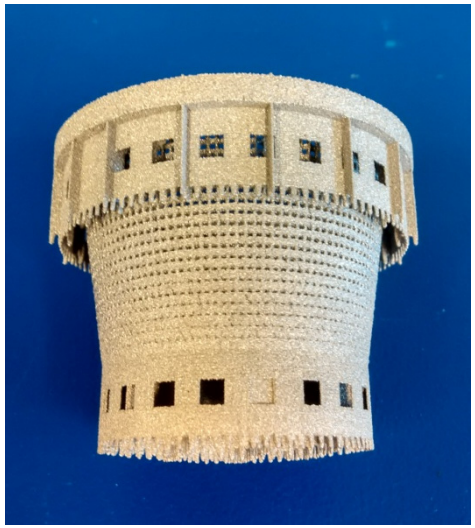
Ice pole tip in CoCr

Ski bindings

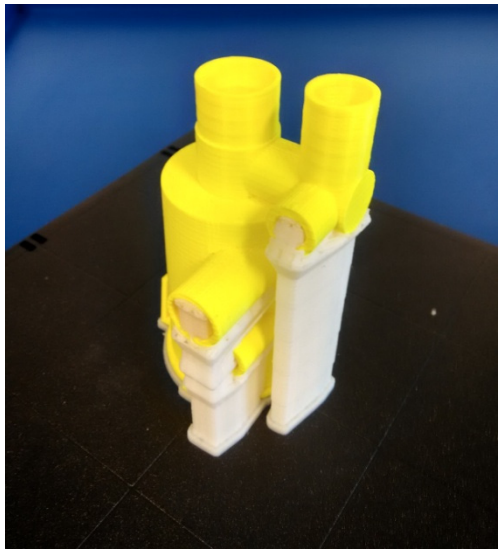
AM FOR SPORTS TECHNOLOGY

Prototyping and construction elements

Field Douglas Bag Valve (ABS)



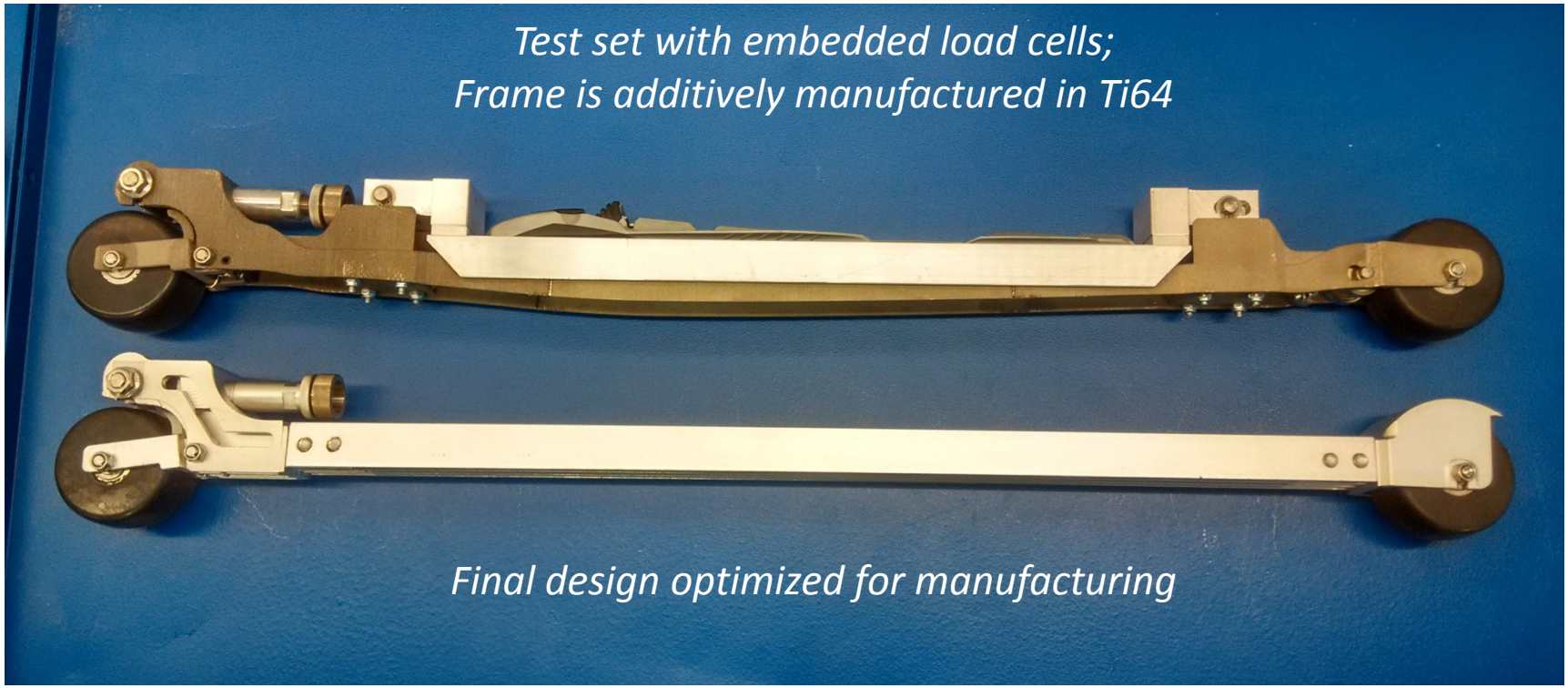
Camp gas burner Head (Ti64)



Part for gas flow system (ABS)

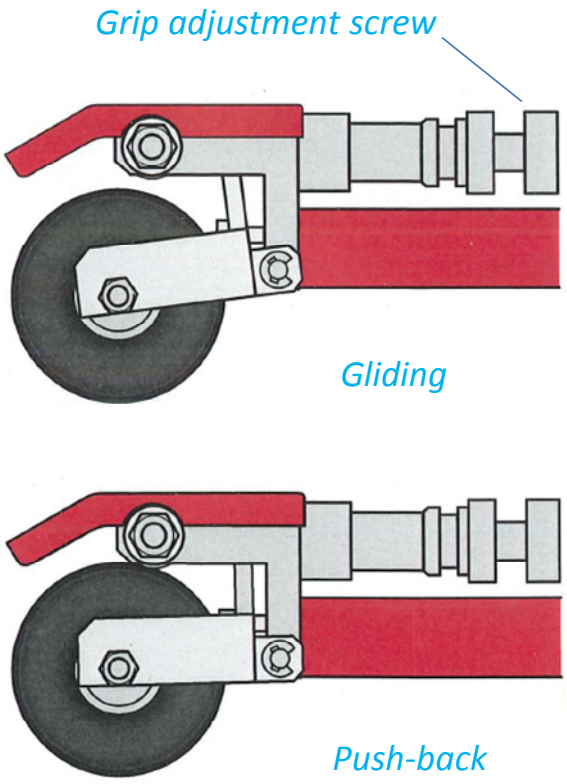
AM FOR SPORTS TECHNOLOGY

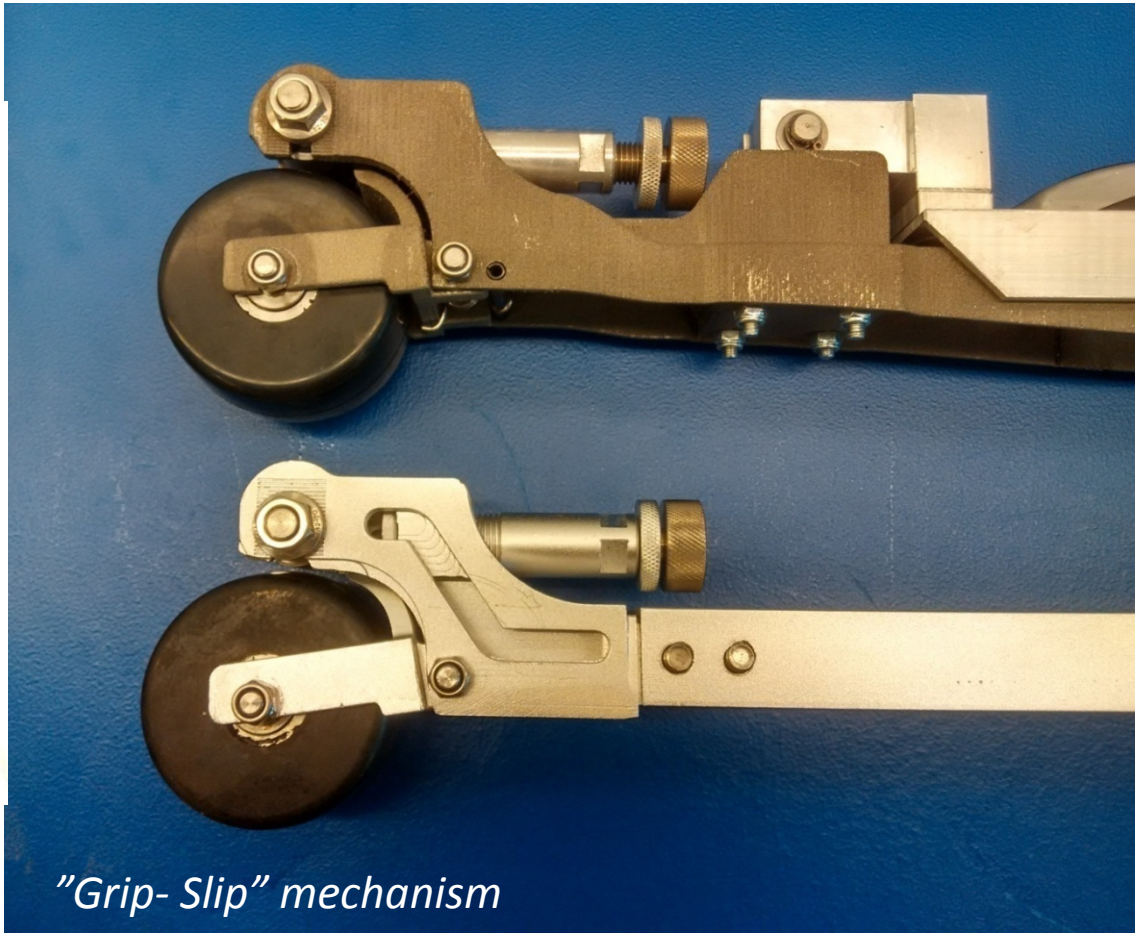
Prototyping and construction: "Challenger" roller skis



AM FOR SPORTS TECHNOLOGY

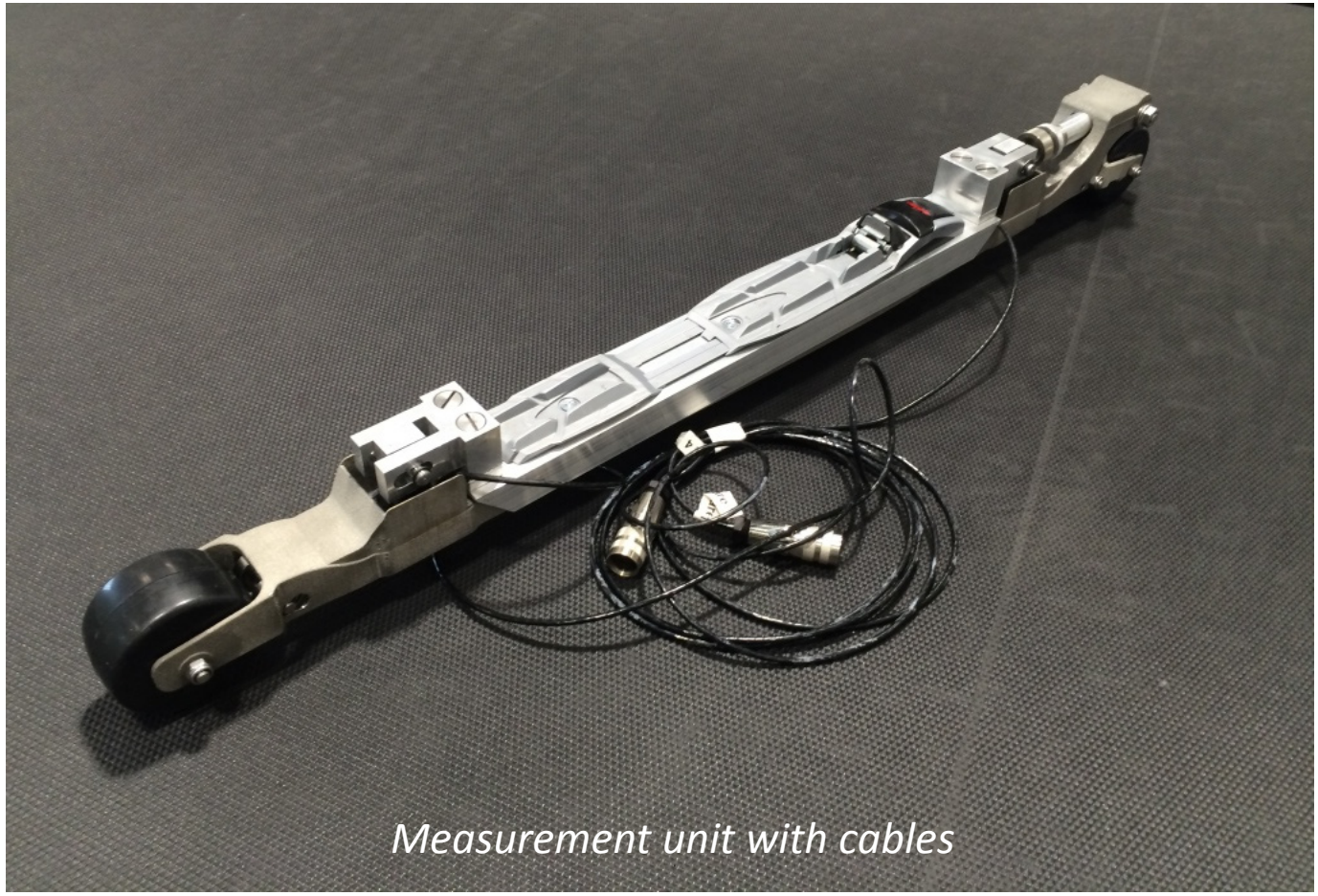
"Challenger" roller skis





AM FOR SPORTS TECHNOLOGY

"Challenger" roller skis



Measurement unit with cables

AM FOR SPORTS TECHNOLOGY

Lightweight elements- bike

Elements of the frame

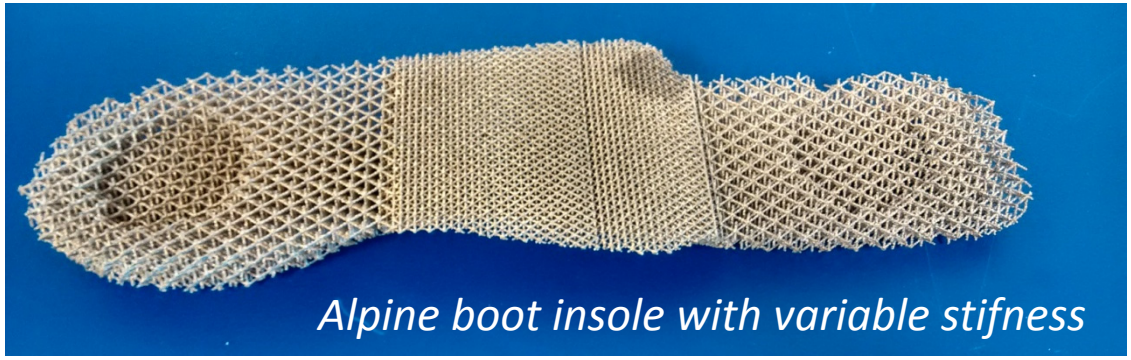
Crankshaft

Courtesy of AIM Sweden AB

aim
ADDITIVE INNOVATION AND MANUFACTURING SWEDEN

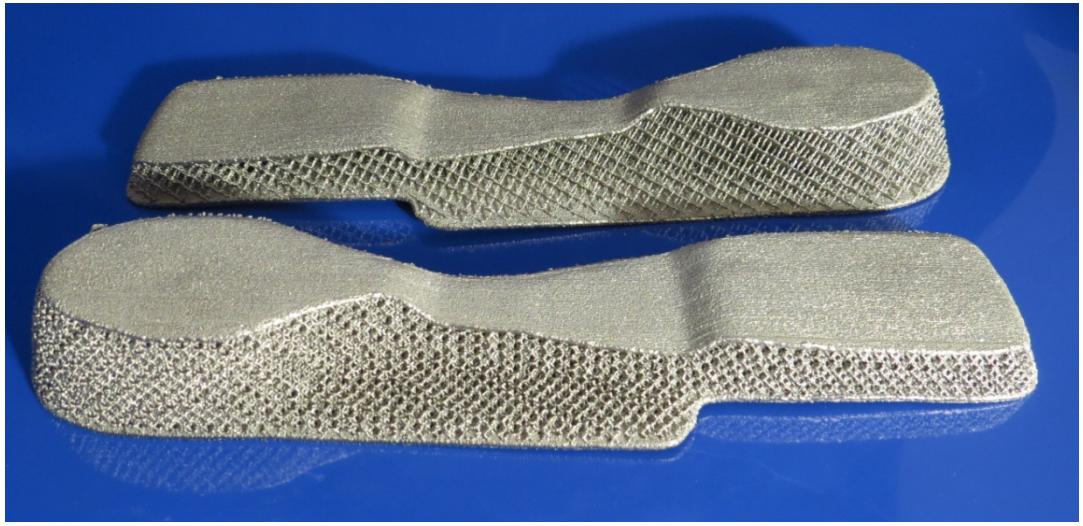
AM FOR SPORTS TECHNOLOGY

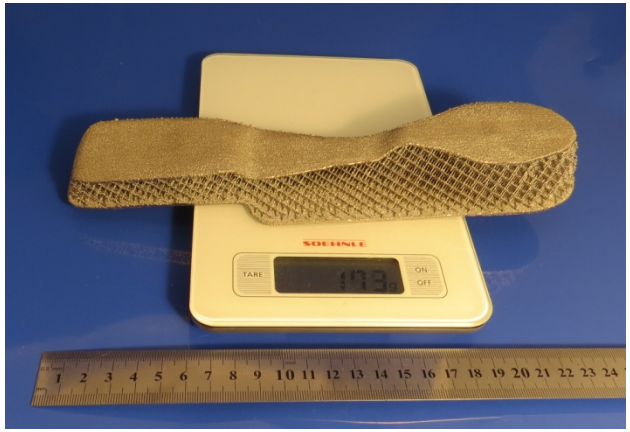
Lightweight elements- alpine skiing



Alpine boot insole with variable stifness

Lilghtweight,
Stiff insoles
(Ti 64)





AM FOR INJURY PREVENTION

Guards and other protection elements

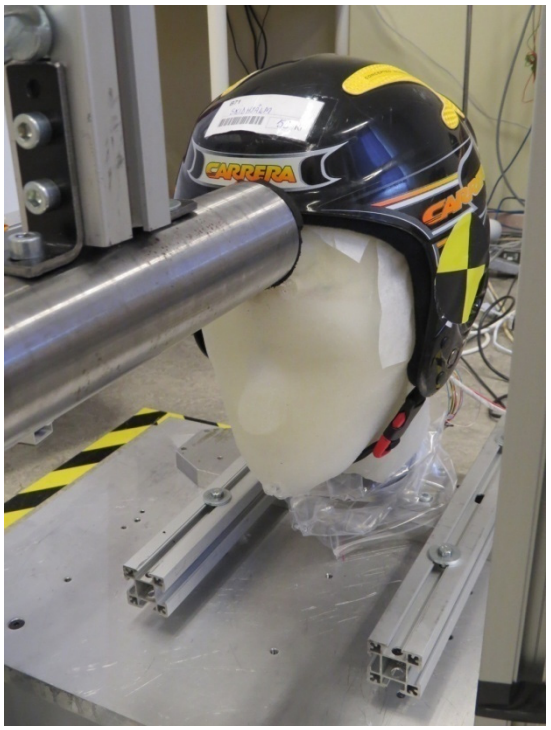
Individually fit shin guards
Material: ABS

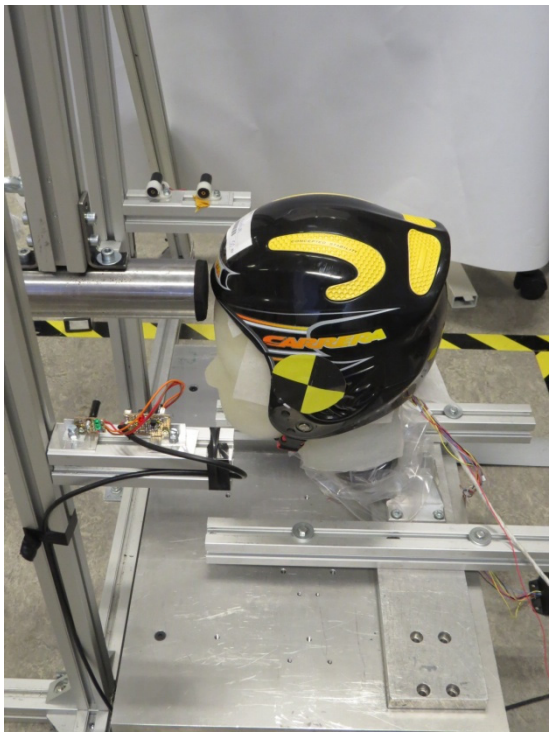
AM FOR INJURY PREVENTION:

PHYSICAL MODELING

SURROGATE HEAD

for helmet tests and brain injury mechanism studies





"Artificial head" with rubber "skin", eight 3-axis accelerometers and two gyroscopes in its rubber brain, and eight pressure sensors in ABS scull monitoring dynamics of the pressure in the "cranial fluid" (silicone oil)

icSPORTS 2017
5th International Congress on Sport Sciences Research and Technology Support

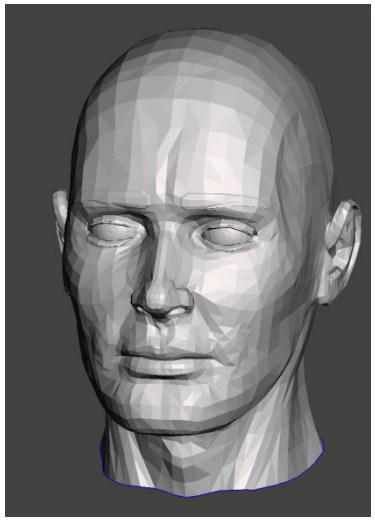
Funchal, Madeira, Portugal, 30-31 October, 2017

Sports Tech Research Centre

PIXEL-TO-PROTOTYPE ROUTE

Making CAD files basing on the CT image

Separating for the 'elements': scull, brain, skin:
Scull is additively manufactured in ABS



Giovanni Carraro, Padova University- Master Project at Sports Tech

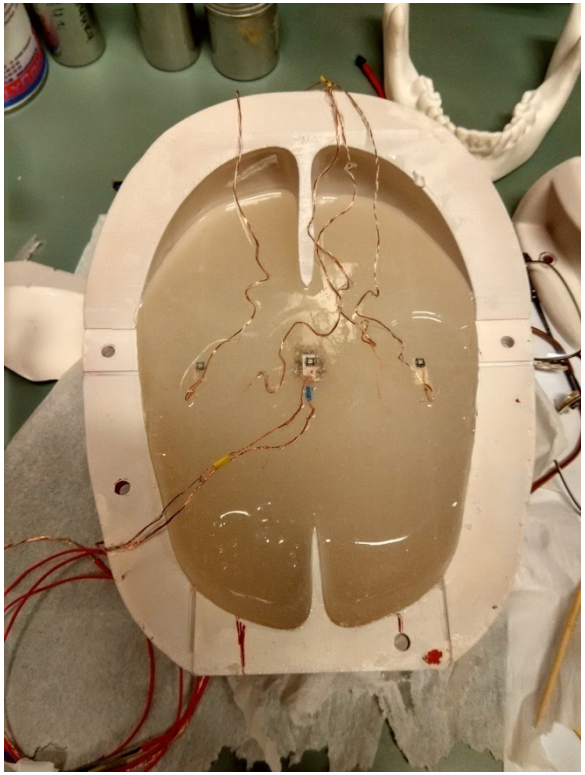
icSPORTS 2017
5th International Congress on Sport Sciences Research and Technology Support

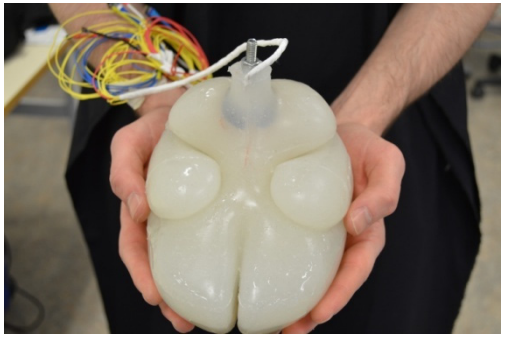
Funchal, Madeira, Portugal, 30-31 October, 2017

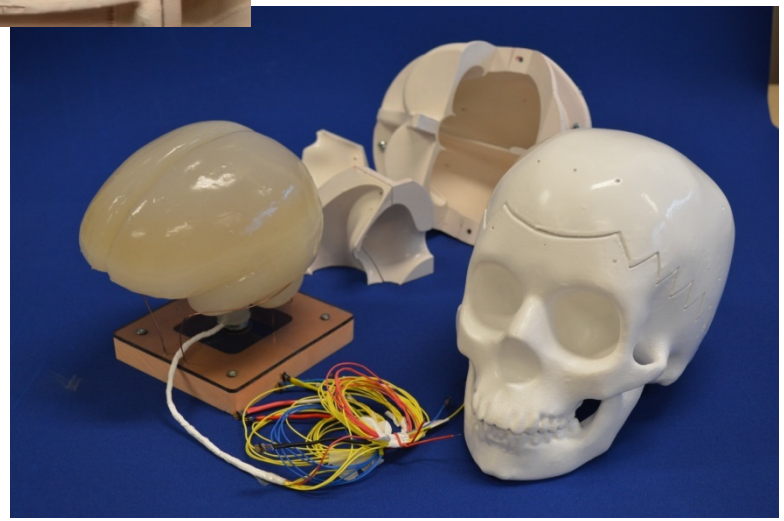
Sports Tech
Research Centre

PIXEL-TO-PROTOTYPE ROUTE

Making molds for the "brain" (ABS); casting it in silicone rubber, embedding sensors one by one

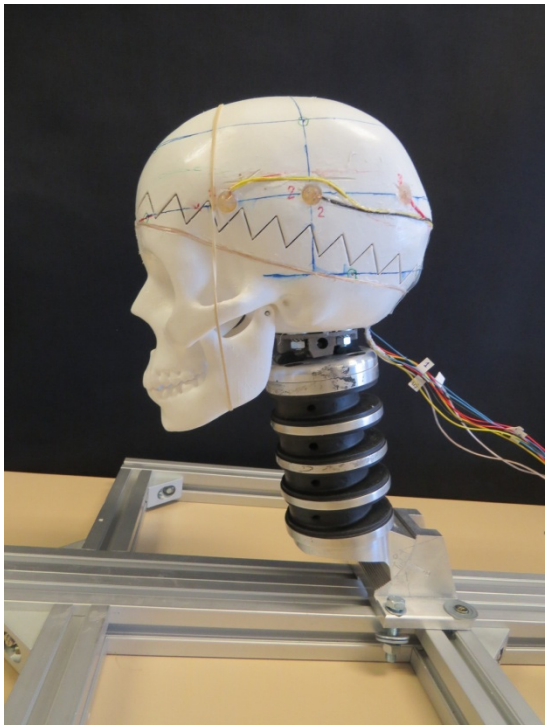


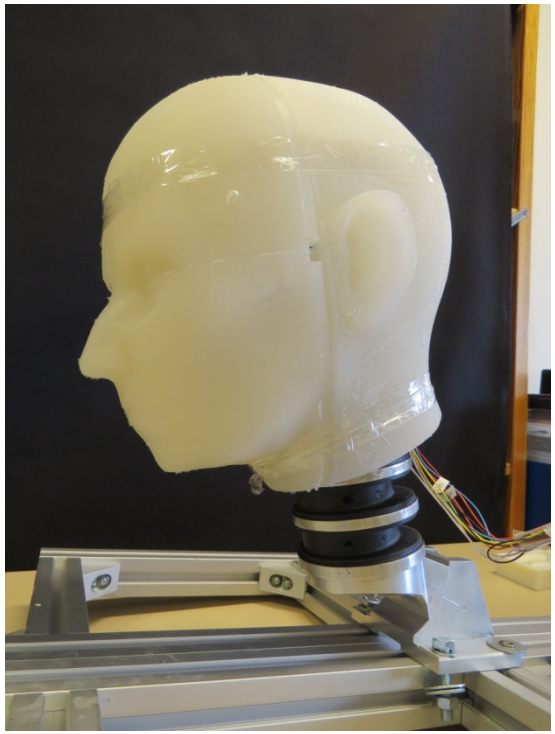




PIXEL-TO-PROTOTYPE ROUTE

Designing and making molds for the skin (ABS); casting it in silicone rubber, embedding pressure sensors into the scull, assembling, filling with oil

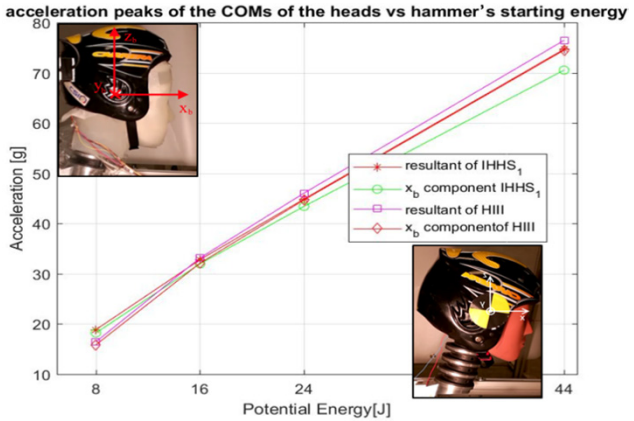


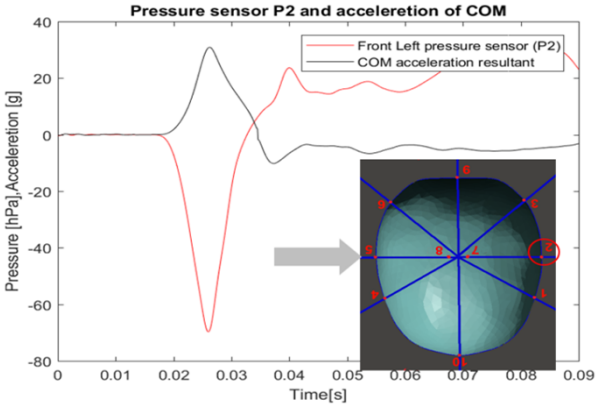


Stefano Dal Castello, Padova University- Master Project at Sports Tech

PIXEL-TO-PROTOTYPE ROUTE

Designing and constructing impact rig, performing tests



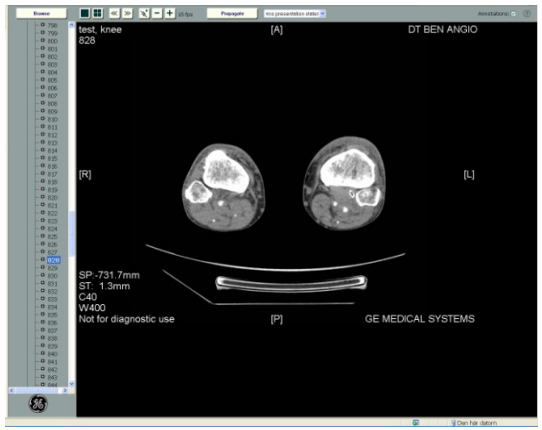


"A novel Instrumented Human Head Surrogate for the impact evaluation of helmets"
To be presented at ISEA-2018, Brisbane, Australia

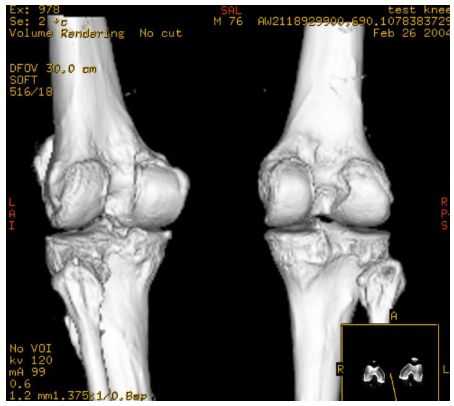
Luca Broggio, Padova University- Master Project at Sports Tech

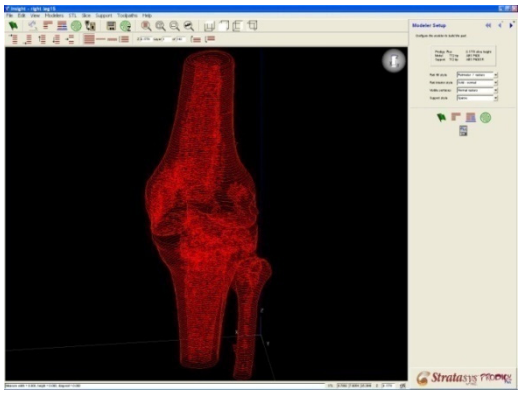
AM FOR INJURY TREATMENT

AM is ”an extension of VR world”: pixel-to-implant



Polymer: Pre-op models

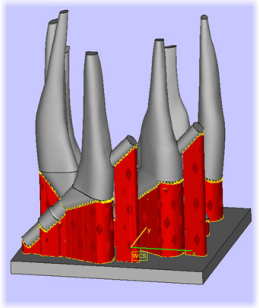




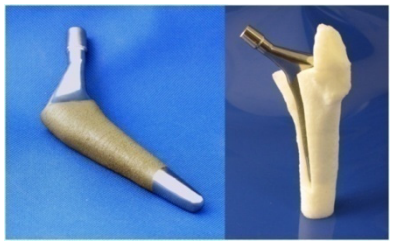
Metal: Implant

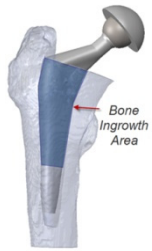
AM FOR INJURY TREATMENT

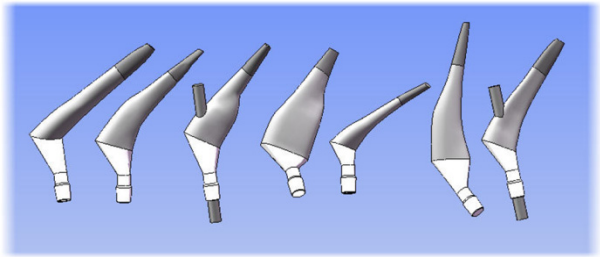
AM is very good for making implants in metal:



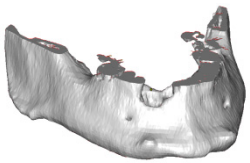
- Formally approved alloys like Ti6Al4V, CoCr;
- Patient specific implants;
- Conformal fixation plates;
- Integrated porous structures
- Cost competitive with other manufacturing methods
  - ➢ ”Complexity comes for free!”

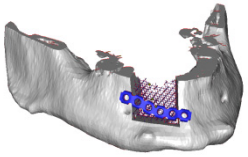


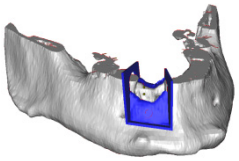


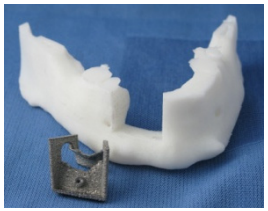


- Special tools for surgery





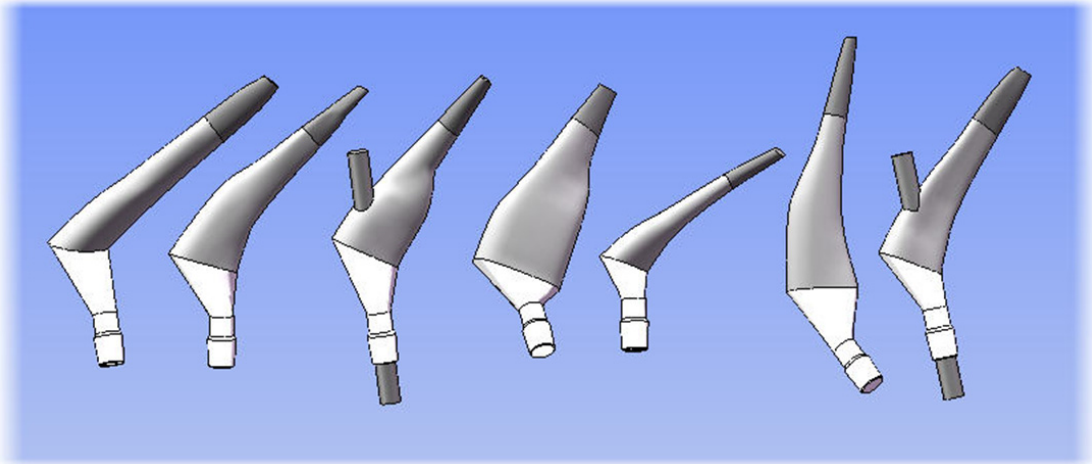


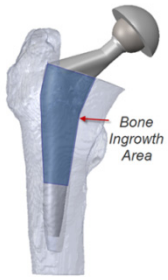


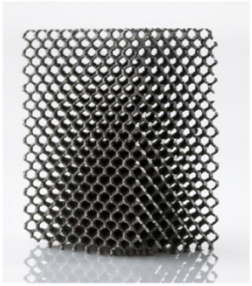
Surrogate operation

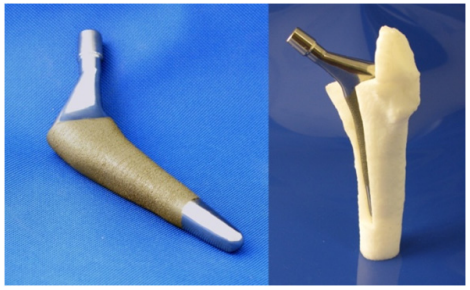
AM FOR INJURY TREATMENT

Individualized hip implants: cost comparison









EBM-results in % of the cost of conventional manufacturing

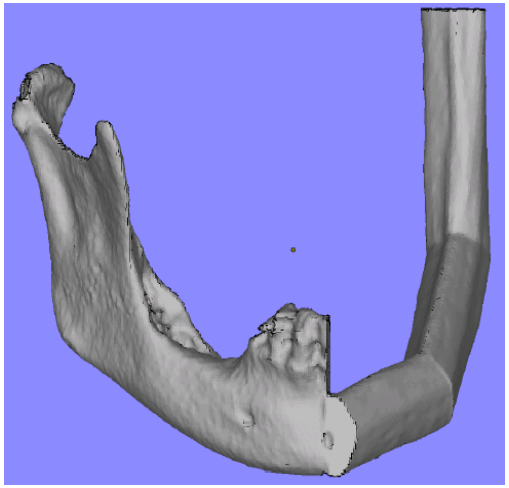
- Material: 15%
- File preparation: 8%
- Manufacturing: 130%

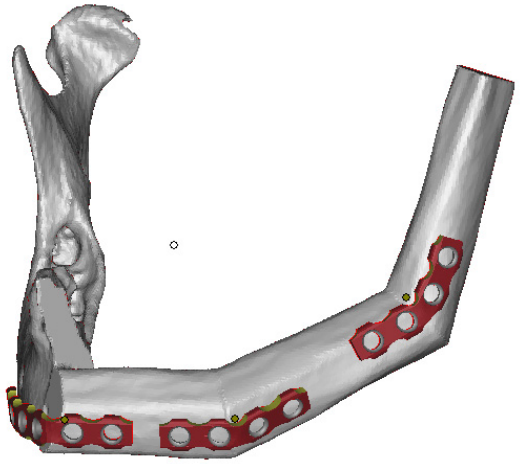
Total: 65%

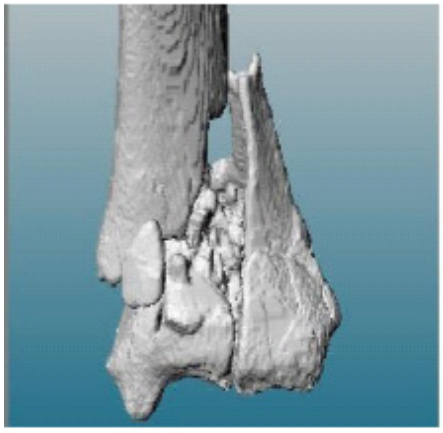
These are just COSTS, we are not ot considering the shorter operation time and better prospects for patient

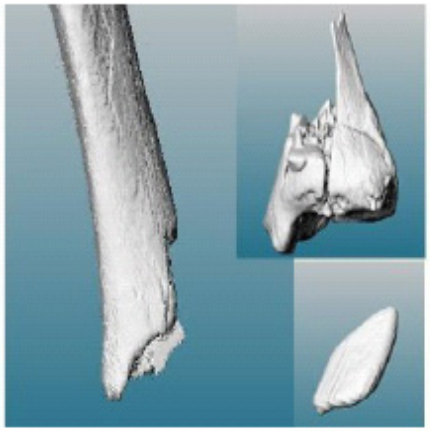
AM FOR INJURY TREATMENT

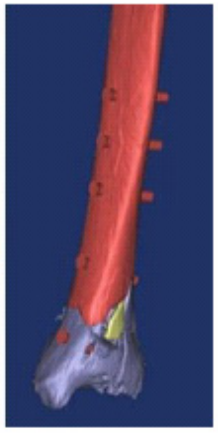
Reconstructive surgery









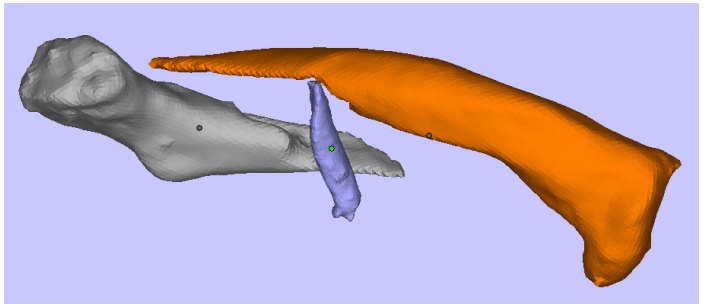


AM FOR INJURY TREATMENT

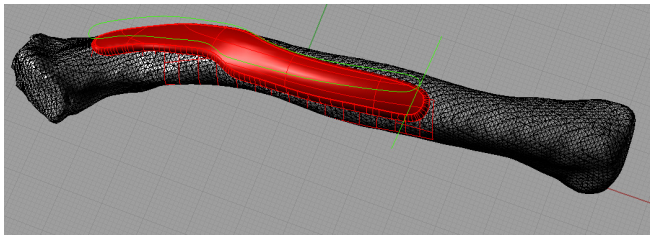
From individualized shape to functionalization: clavicle

Broken collar bone case: fixation plate shape design

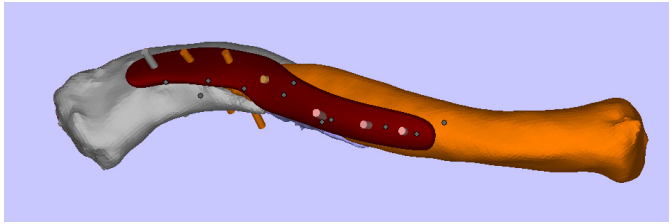
CAD file - from CT scan



Fixation plate over mended bones



Design for best screw hole placement



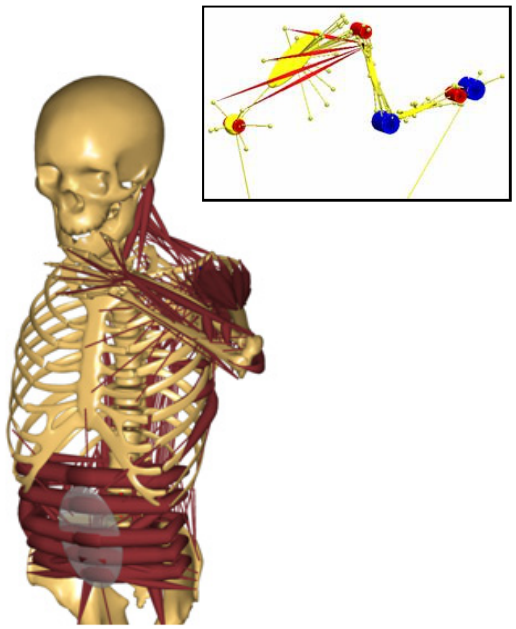
Fixation plate is optimized for the ligament positions;

Screw hole position is optimized

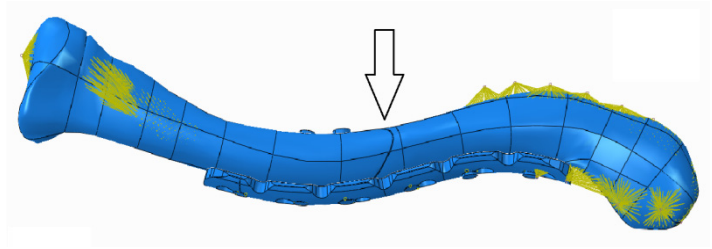
AM FOR INJURY TREATMENT

Functional fixation plate design optimization

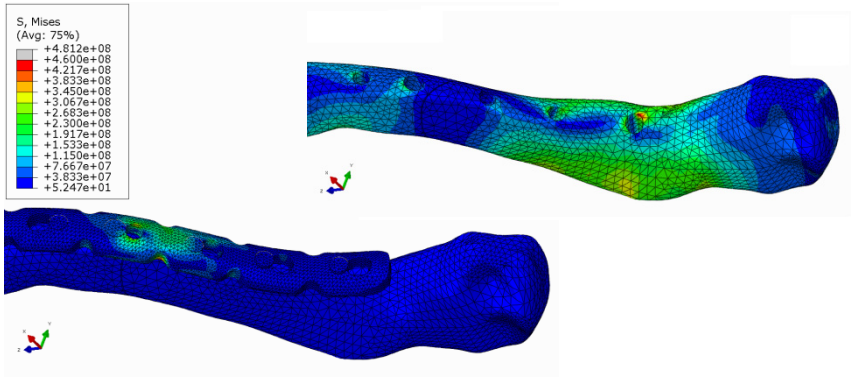
Musculoskeletal simulation



http://www.anybodytech.com/



Model incorporating ligament positions and applied forces

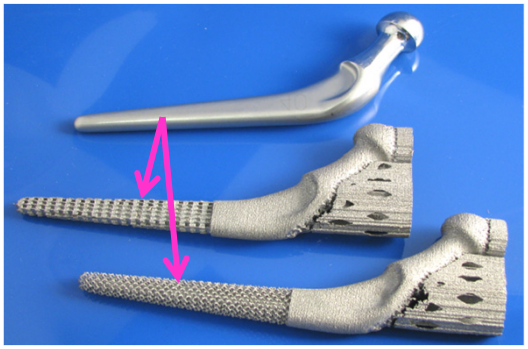


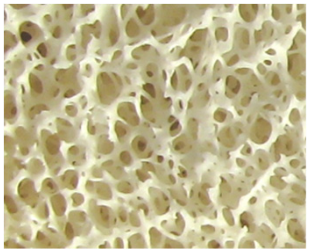
Simulation of the stress in the fixation plate and mended bone

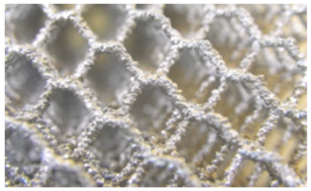
AM FOR INJURY TREATMENT

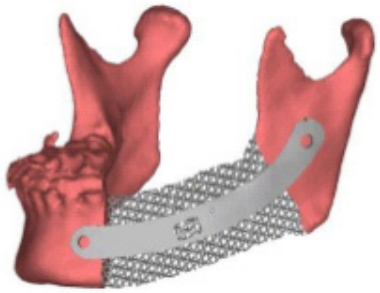
Metal lattices

3D lattices (mesh, net structures)
in biomedical implants
are designed to replace
natural spongy bone structure



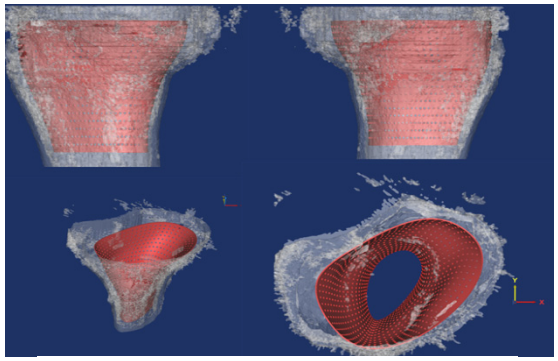


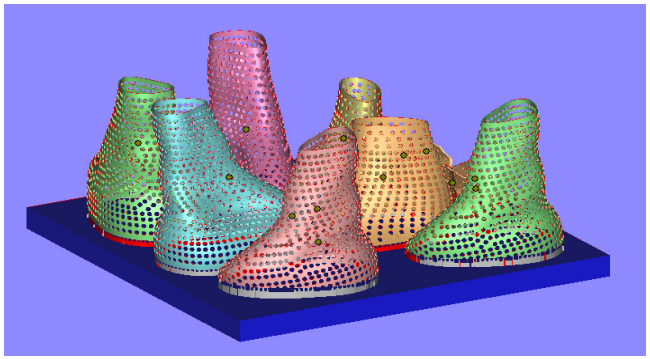


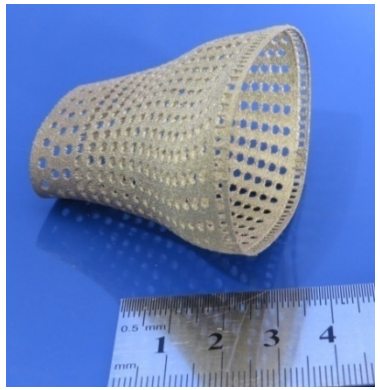


AM FOR INJURY TREATMENT

Lightweight metal reinforcement cages



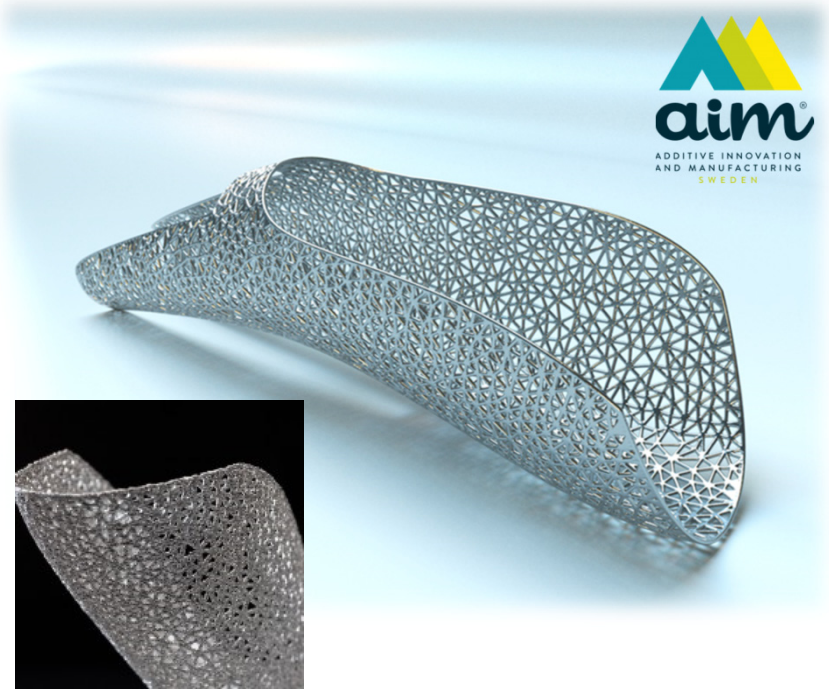


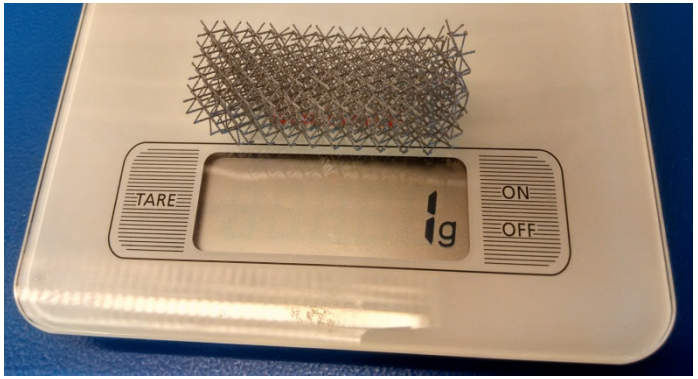


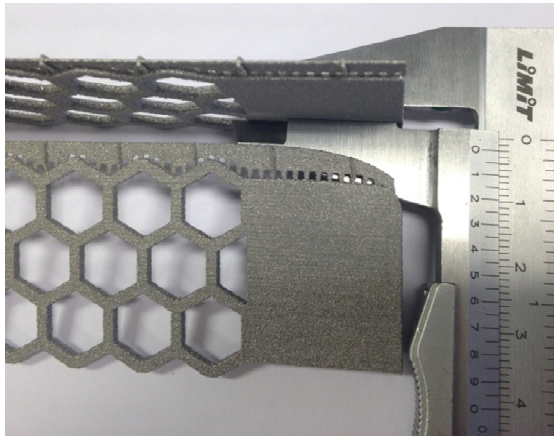
Results 15 weeks (left) and 52 weeks (right) after operation

AM FOR INJURY TREATMENT

Lightweight metal reinforcement structures







Courtesy of AIM Sweden AB.
Engineered and designed by ELiSE Leichtbau

AM FOR PARA-SPORTS

MIUN.SE
DISCOVER YOUR OPPORTUNITIES

Advanced prosthesis for cross-country skier

Alpine sitski elements

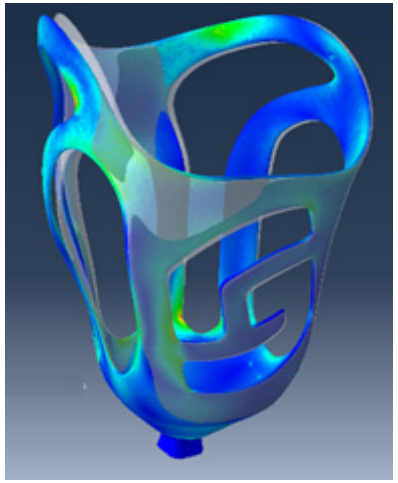
icSPORTS 2017
5th International Congress on Sport Sciences Research and Technology Support

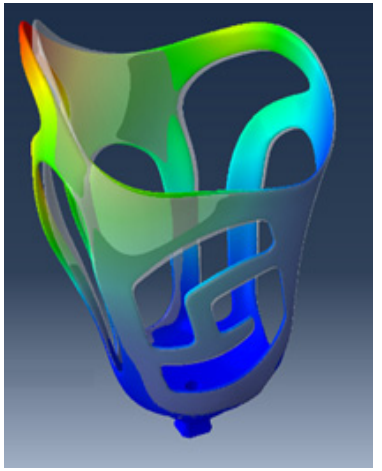
Funchal, Madeira, Portugal, 30-31 October, 2017

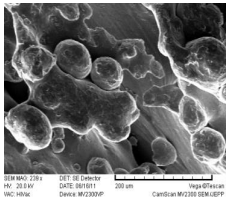
Sports Tech Research Centre

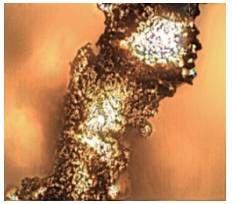
PROSTHETIC SOCKET IN TI64

MIUN.SE
DISCOVER YOUR OPPORTUNITIES









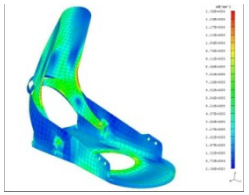
icSPORTS 2017
5th International Congress on Sport Sciences Research and Technology Support

Funchal, Madeira, Portugal, 30-31 October, 2017

Sports Tech Research Centre

LITTLE SUMMARY

AM or 3Dp can be quite useful in many sports- and health-related applications
I was able to show only some examples


- It is a new technology and is not a 'push-button' one yet
- It is rather "green" technology
- It has good value for money in the products, when used properly
- It provides very wide possibilities, "sky is your limit":
  - freedom of shapes
  - wide material choice, new materials are becoming available

- But to use it sucessfully one needs to know how to deal with it:
  - what are its limits
  - which applications would benefit most from using it
  - how one shuld design things for AM

FUTURE TRENDS

MIUN.SE
DISCOVER YOUR OPPORTUNITIES

Everybody having a desktop 3d-printers for everything?

NO

We believe in the deepening ‘Corporate’ approach

- High-end professional equipment used by highly qualified specialists:
  better economy, better quality control, higher efficiency, better recycling
- Advanced networking and ‘distributed‘ manufacturing:
  ‘one-stop-shop for ordering, design and manufacturing are done in other locations
- Growing awareness of professionals
  e.g. changes in design paradigm etc.
- New advanced materials specifically designed for AM
- Components with anisotropic spatial properties; composite materials

Art Installation
”Utopian implants för the future”
Malin Matilda Allberg
(www.malinmatilda.com)

KEY TO FUTURE SUCCESS

MIUN.SE
DISCOVER YOUR OPPORTUNITIES

- Wide cooperation of all parties involved:
  - Industry- Companies and R&D Institutions;
  - Academia- Research organizations;
  - Education- Universities, Schools;
- Cooperation at national and international levels: state programs, EU programs, international funds
- Active education in AM:
  - Increasing general knowledge on AM;
  - Teaching ‘new design paradigm’;
  - Hands-on approach- using AM machines in teaching
- Using AM where it provides largest benefits

Thank you for your kind attention!

Questions?