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# Recycling of the ballistic polyethylene waste

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# Recycling of the ballistic polyethylene waste

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- ANALYSIS OF THE GOOD PRACTICE
- TANGIBILITY, DURABILITY AND VISIBILITY OF THE GOOD PRACTICE
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- TRANSFERABILITY OF GOOD PRACTICE

**About the Institute**

Institute of Security Technologies "MORATEX" is a research institute according to Journal of Laws of 2010 No. 95, Item 1513, as amended, established by the Minister of Interior and Administration.

The subject of our activities is performing the research and development works to develop new technical and technological solutions in the field of manufacturing the equipment and materials used for the production of armor, fire and health as well as other protective related products.

MORATEX is also a legal body No. 4473 under the directive IS 1606/EC regarding the personal protection equipment (PPE).

**GOOD PRACTICE INFORMATION**

**AIM:**  
The main aim of the GP is to develop the method for the economic re-fabrication of the ballistic protections based on the UHMWPE (ultra-high molecular weight polyethylene) fibres after usability time to functional raw – sources and functional products.

**Stakeholders involved**

- 1) end-users of the ballistic protection (military units in security area and the military forces as well as services responsible for security persons and security guards);
- 2) manufacturer of the ballistic protection being responsible in several cases for the collection of the product after the pre-governed period as well as the same resulting from manufacturers;
- 3) scientific institution as a user of the user generated knowledge for the commercial utilization of the products made of the hardy or non-degradable materials.

**Defined content and describing the Good Practice**

The complete idea of the re-fabrication or re-manufacture of the ballistic protection made of the UHMWPE fibres covered the full the cycle chain of the polyethylene ready to use, after the de-fabrication to the GP provided for the production of several multifunctional products, namely in composite equipment.

The idea of the re-design and eco-design proposed by Professor [1] with own implementation [2] was a base for the GP acceptance.

**The 1<sup>st</sup> phase of the recycling: fragmentation & grinding**

The ballistics protection for the fragments of UHMWPE fibres was the green ballistics ready.

**ANALYSIS OF THE GOOD PRACTICE**

**Relevance of the Good Practice to the policy theme**

The proposed GP will improve the effectiveness (economic and performance) as well as safety aspects of the re-fabrication possibility of the ballistic protections (personal or for transportation means and buildings) in frame of the new, innovative multifunctional products design (by eco- and re-design procedures).

**Relevance of the Good Practice to the policy theme**

The ballistic protection that has the functional properties and safety performance as well as innovative waste are usually considered by the companies being their manufacturers – it proposed the greenhouses effect, due to the re-fabrication of the GP.

The main idea of the nucleus of the waste from the ballistic protection structures as well as production-waste allows to reduce the greenhouse effect and to be in line with the eco- or products with entirely defined multifunctionality.

**Relevance on the durability of the GP results and impact**

The durability of the GP is not limited due to the observed growth of UHMWPE fibrous materials application. The GP has to be widely applicable to other products made of the above-mentioned materials as well based on the other polyethylene, developed which increases every year.

**Added-value of the practice in terms of innovativeness, effectiveness and efficiency**

The main administrative efficiency is the critical change in respect of the possibility to utilize the post-manufacture and pre-use products & materials that will affect the environmental efficiency, economical recovery of the above-mentioned products as well as the implementation of the redesign and eco-design ideas in practice, taking into consideration the reconstruction of the energy and materials losses by the reduced performance, it will strongly enhance the horizontal policy of the EU as well as sustainable development of every sector of industry that uses the polyethylene materials, including fibrous forms.

**Conditions and requirements of GP transferability**

- Long and short terms contact impacts on GP feasibility and transferability in terms of economic, political, social and cultural environment, involvement of special competences and skills.

**Conditions and requirements of GP transferability**

The transferability of the GP is not entirely limited due to the observed growth of UHMWPE fibrous materials application.

The GP idea is easily adaptable to recycling of other products made of the above-mentioned material as well as based on the other polyethylene, developed which increases every year.

In respect of the geographical localization and mobility of expertise for the recycling, it is indicated high flexibility and adaptability, considering the economic, social and cultural environment.

**Long and short terms contact impacts on GP feasibility and transferability in terms of economic, political, social and cultural environment, involvement of special competences and skills**

The critical aspects affecting the long and the short terms impacts are specific competences and skills in the area of redesigning the UHMWPE fibrous materials.

This one will be reduced by the transfer of the competences in subject matter, its education and training support.

**RESET**  
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Thank you!



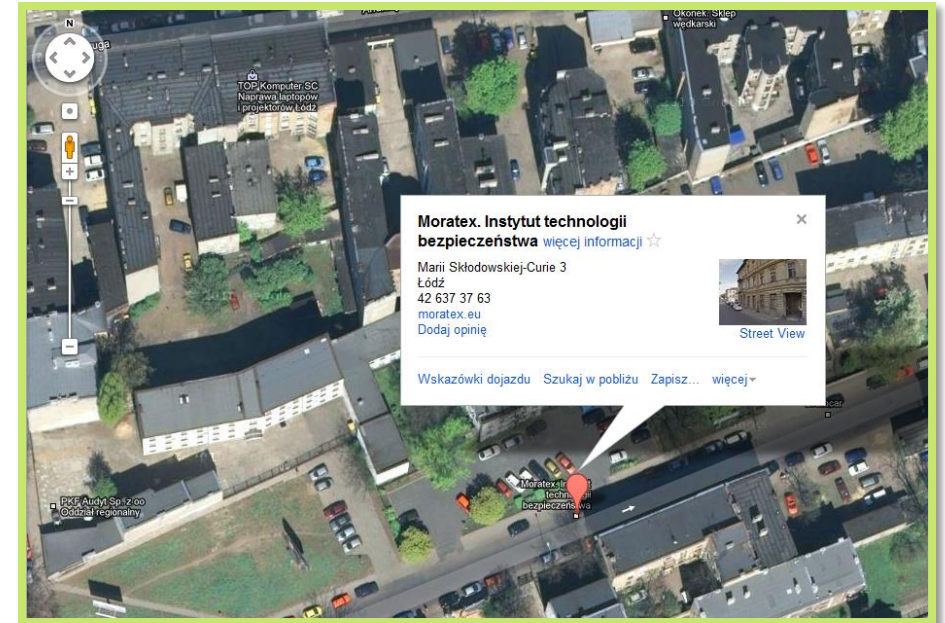
## Content

- **GOOD PRACTICE INFORMATION**
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- **TRANSFERABILITY OF GOOD PRACTICE**



## About the Institute ...

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  - The subject of our activities is performing the research and development works to develop new technical and technological solutions in the field of manufacturing the equipment and individual means for the protection of human life and health as well as to transfer them into industrial practice.
- MORATEX is also a notified body No. 1475 under the directive 89/686/EEC regarding the personal protection equipment (PPE).



Google Map



## GOOD PRACTICE INFORMATION

### AIM:

The main aim of the GP is to develop the method for the economic re-fabrication of the ballistic protections based on the UHMWPE (ultra-high molecular weight polyethylene) fibres after usability time to functional raw – sources and functional products.

## Stakeholders involved

The main stakeholders of the GP are:

- 1) end-users of the ballistic protections (services acting in security area and the military forces as well as services responsible for securing persons and sensitive goods;
- 2) manufacturers of the ballistic protections being responsible in several cases for the utilization of the product after live-guaranteed period as well as the wastes resulting from manufacture;
- 3) scientific institution as a user of the new generated knowledge for the commercial utilization of the products made of the hardly or non-degradable materials.

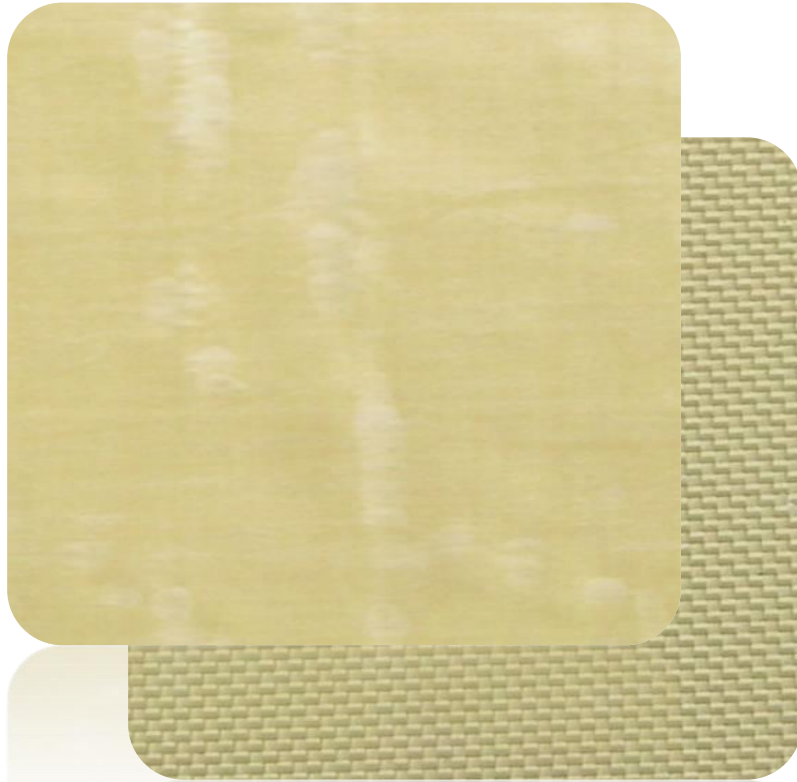
## Detailed content and developing the Good Practice

[1] Victor Papanek, *Dizajn dla realnego świata, Środowisko człowieka i zmiana społeczna*, Wydawnictwo Recto verso, Łódź 2012

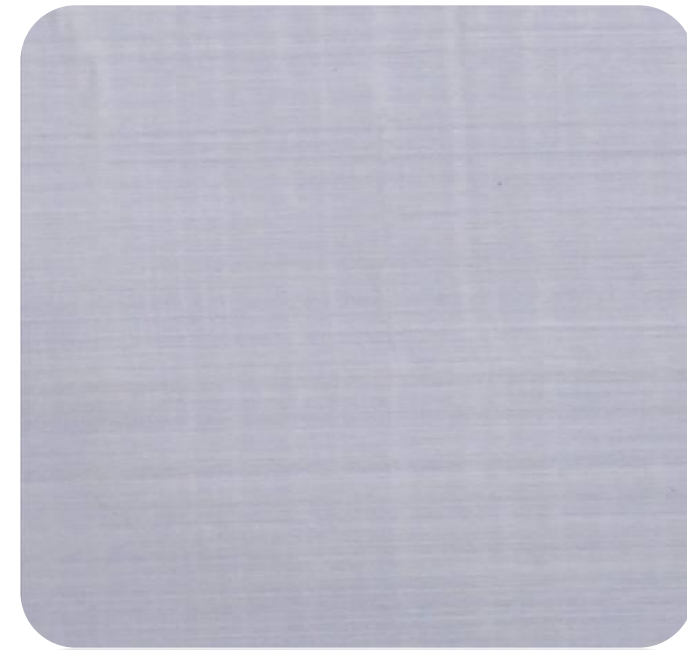
[2] M. H. Struszczyk, *Design or Development of the Advanced Haemostatic Topical Agents*, Proceedings Book of Polysaccharides and polysaccharides-based advanced materials: from science to industry, 4th EPNOE International Polysaccharide Conference, 2015, 100

The complex idea of the re-fabrication or re-manufacture of the ballistic protection made of the UHMWPE fibers assumed the full life cycle chain of the polyethylene ready to use, after the de-fabrication to the PE granulate, for the manufacture of several multifunctional products, mostly in composite segments.

The idea of the re-design and eco-design proposed by Papanek [1] with own implementation [2] was a base for the GP assumptions.



🌐 para-aramid woven and fibrous composite (Kevlar<sup>®</sup>, Twaron<sup>®</sup> GoldFlex<sup>®</sup>)



🌐 UHMWPE fibrous composite: (Dyneema<sup>®</sup>, Spectra<sup>®</sup>)



**KEY PROJECT No. WND-POIG.01.03.01-10-005/08**  
**„MODERN BALLISTIC BODY ARMOURS AND COVERS FOR TRANSPORTATION MEANS AS WELL AS FOR BUILDINGS, MADE ON A BASIS OF FIBROUS COMPOSITES”**

Realisation: 01.09.2007 – 30.06.2012  
 Project Value: 3 250 538,09 €  
 European Union Fund: 2 763 291,08 €

The Key Project is realized within the frame of INNOVATIVE ECONOMY, NATIONAL COHESION STRATEGY 2007-2013, Priority 1 - Research and development of new technologies, Axis 1.3 - Support for R&D projects for entrepreneurs carried out by scientific entities, Subaxis 1.3.1 - Development projects

**3 PROTOTYPES OF BULLET- AND FRAGMENT-PROOF VESTS**

- a prototype of quick-release bullet and fragment-proof vest
- a prototype of transport bullet and fragment-proof vest (vest and hip belt)

**MODULAR QUICK-RELEASE BULLET- AND FRAGMENT-PROOF VEST**  
 Indicated for the use of internal security.

**7 VARIANTS OF BALLISTIC INSERTS FOR BULLET- AND FRAGMENT-PROOF VESTS**

Type of ballistic panel	Ballistic resistance according to PN-V 8700:1999 Standard	Ballistic resistance according to PN-V 8700:2011 Standard
Fibrous Composite	K2, K4	K3A (7.62x39mm; PS: 720 <sup>m</sup> /m/s)
Ceramic & Fibrous Composite of Type I	K2, K4, resistance to 2500J bullet	K3A (7.62x39mm; PS: 720 <sup>m</sup> /m/s) K3B (5.56x45mm; 2210J, 920 <sup>m</sup> /m/s)
Ceramic & Fibrous Composite of Type II	K2, K4, resistance to SAR bullet	K3A (7.62x39mm; PS: 720 <sup>m</sup> /m/s) K3C (7.62x31mm; FMJ; 840 <sup>m</sup> /m/s) K3A (7.62x39mm; AP; 820 <sup>m</sup> /m/s)

**HYBRID BALLISTIC HELMETS**  
 Resistance to fragments according to PN-V 8700:2011 Standard  
 Helmet should protect the head of soldier above the eyebrows level, at sides - above the ear level behind the chinstrap, and at back - above the occiput. At the  $v_0 = 800$  m/s at the acceptable dynamic deflection (deform) below 20 mm (class C).  
 Multiprotection according to PN-V 8700:2011 Standard

Class of helmet/armor	Type of ammunition	Bullet weight (g)	Measured velocity of bullet (m/s)
K2	307 Magnum	220	220
	81 (7.62)	10.7	220
	7.62	8.8	220

**THE BULLET- AND FRAGMENT-PROOF VEST**  
 Indicated for the use of internal security.

**BALLISTIC SHIELD**

- FABRIK 308 Winchester (PS) at the bullet velocity of  $v = 800$  m/s.
- FABRIK 308 (PS) at the bullet velocity of  $v = 710$  m/s.

**THE BULLET- AND FRAGMENT-PROOF QUICK-RELEASE VEST**  
 Indicated for the use of internal security.

**WE INVEST IN YOUR FUTURE**

**SUBSIDIES FOR INNOVATIONS**

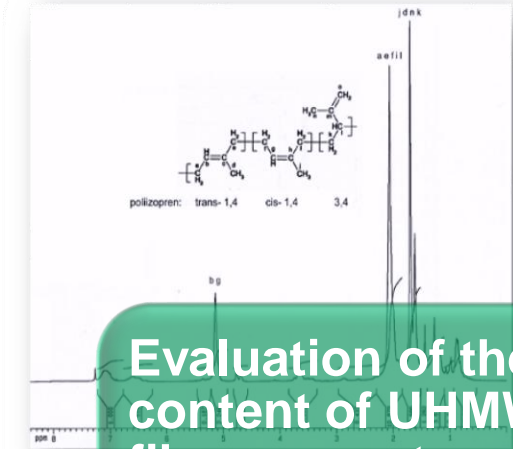
The Project realized within the frame of INNOVATIVE ECONOMY, NATIONAL COHESION STRATEGY 2007-2013, is co-funded in 85% by the European Union from the European Regional Development Fund and in 15% by the Polish Ministry of Regional Development

- Dyneema® UHMWPE fibers made of gel-spinning technology developed in 1979;
- Dyneema®: HB – for application in hard (composite) ballistic protections, such as: helmets, anti-fragment protections, armoring systems;
- SB – for application in soft ballistic protection, such as: inserts for bullet-, fragment-proof vests.



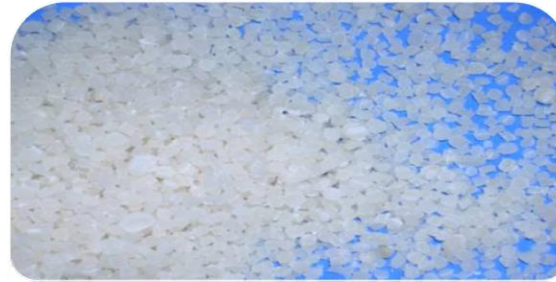
- **post-manufacture wastes originated during manufacture of the ballistic protections and resulted from the variety of the shapes and sizes of the final products.**
- **post-usage products in form of the soft ballistic inserts after guarantee period or products loosing their performance and safety due to the destruction during usage or storing.**





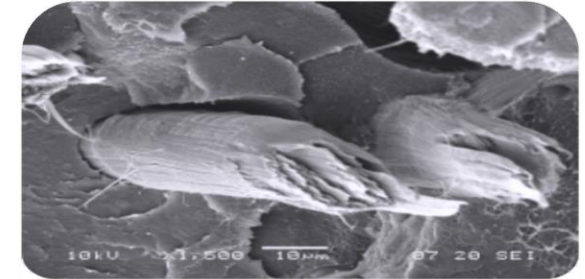
### Evaluation of the content of UHMWPE fibrous wastes

- fibers fraction: 73 wt% (UHMWPE);
- film - matrix: 10 wt% (LDPE);
- binder: 17 wt% (isomers of polyisoprene).



### Re-fabrication of UHMWPE wastes

- fragmentation & grinding;
- re-granulation;
- evaluation of the PE regranulate originated from the UHMWPE fibrous wastes.



### Eco-design & re-design ideas

- Fabrication of the PE composites being the mixture of the defragmented UHMWPE wastes and PE re-granulate;
- Fabrication of the extruded products with the significant content of the PE regranulate.



# The 1<sup>st</sup> phase of the recycling: fragmentation & grinding

The installation prototype for the fragmentation of UHMWPE fibrous wastes (semi-technical scale)



**Introduction of the UHMWPE wastes**



**Defragmented UHMWPE wastes**



**Method for recycling  
products containing  
polyethylene fibers  
with an ultra-high  
molecular weight**

**ITB "MORATEX"  
CBMiM PAN**

**Aggregate for cutting  
the plastics**

**ITB „MORATEX”**



## Financial framework

[3] Zurek W., et al., Wydawnictwa Naukowo-Techniczne, Warszawa, Poland, 1983

[4] Karolinski W., et al., Przegląd Włókienniczy, 1974, 278 – 284

[5] M. H. Struszczyk, et al., in Medicaland Health Care, ISBN 978-952-15-2607-7, FiberMed11 28-30 June 2011, Tampere, Finland

**The economical chain was designed for identification of the optimal status of the reused PE application taking into account the market demand and assumed income. The economic aspects belonged to the main criteria of the selection of optimal product properties based on the criteria evaluation [3-4] with own implementation [4].**

**Evaluation schemes and mechanisms (monitoring, indicators)**

**Several technological processes were modelled to obtain the multifunctional products based on the refabricated PE, such as: granulates, fibres, composites applicable in aimed sectors of industry.**

**The main indicators of the GP are the following:**

- **amount of the recyclable PE used for the manufacture of the multifunctional product: > 20%;**
- **numbers of the new-designed eco- & re-products based on UHMPE fibrous composites after use: > 4.**



# ANALYSIS OF THE GOOD PRACTICE

Relevance of the Good Practice to the policy theme

**The proposed GP will improve the effectiveness (economic and performance as well as safety aspects) of the re-fabrication possibility of the UHMWPE fibrous materials applicable for the manufacture of the ballistic protections (personal or for transportation means and buildings) in frame of the new, innovative multifunctional products design (by eco- and re-design procedures).**



## Relevance of the Good Practice to the policy theme

**The ballistic protections that lose the functional properties and safety performance as well as in-process wastes are usually combusted by the companies being their manufacturers – it propagated the greenhouse effect, due to the escalation of the CO2 emission.**

**The new idea of the reclaim of the wastes from the ballistic protection manufacture as well as products-after-use allows to reduce the greenhouse effect and results in new ideas of eco- or re-products with strictly defined multi-functionality.**



## **TANGIBILITY, DURABILITY AND VISIBILITY OF THE GOOD PRACTICE**

- **GPs tangibility: results and impacts on the partner's policy (e.g. through measurable indicators);**
- **Success factors;**
- **Difficulties encountered and lessons learnt from the practice;**
- **Remarks on the durability of the GP results and impacts;**
- **Possible leverage effect to trigger further improvements in policies and know-how.**

**GPs tangibility: results and impacts on the partner's policy**

**The implementation of this GP to the practice in other regions of EU allows to reduce the amount of the high-tech materials utilization by combusting, increase the product-manufacture-energy demand efficiency as well as allows for prolongation of the life cycle of the polyethylene by the new idea of the re- or eco-products manufacture based on the materials isolated with the ecological-friendly method, from the wastes of the ballistic protection manufacture as well as the products-after-use.**

## Success factors

**The success factor of the presented GP is mostly connected with the optimal implementation of logistic idea of the one-place combination of the UHMWPE fibrous waste hoarding with the re-fabrication/re-manufacture based on the assumption of the GP.**

**Difficulties encountered and lessons learnt from the practice**

**The main issue of the proposed GP is to amass the infrastructure for selection, re-fabrication and re-manufacture at one place, geographically identical.**

**Remarks on the durability of  
the GP results and impacts**

**The durability of the GP is not limited due to the observed growth of UHMWPE fibrous materials application. The GP idea is easily adaptable to other products made of the above-mentioned materials as well based on the other polyolefins, demand of which increases every year.**

**Possible leverage effect to trigger further improvements in policies and know-how**

**Due to the easy adoption in aspect of the localization as well as sources for the recycling, the proposed GP shows high flexibility and adaptability taking into the account leverage effect to trigger further improvements in policies and know-how.**



## ADDED-VALUE OF THE GOOD PRACTICE

Added-value of the practice in terms of innovativeness, effectiveness and efficiency

The main added-value efficiency is the critical change in aspect of the possibility to utilize the post-manufacture and post-use products & materials that will affect the environmental efficiency, economical reclaim of the above-mentioned products as well as the implementation of the redesign and eco-design ideas to practice, taking into consideration the maximization of the energy and materials usage to the obtained performance. It will strongly influence the horizontal policy of the EU as well as sustainable development of every sector of industry that uses the polyethylene materials, including fibrous forms.





## TRANSFERABILITY OF GOOD PRACTICE

- **Conditions and requirements of GPs transferability;**
- **Long and short terms context impacts on GP feasibility and transferability in terms of economic, political, social and cultural environment, involvement of special competencies and skills.**

## Conditions and requirements of GPs transferability

**The transferability of the GP is not strictly limited due to the observed growth of UHMWPE fibrous materials application.**

**The GP idea is easily adaptable to recycling of other products made of the above-mentioned materials as well as based on the other polyolefins, demand of which increases every year.**

**The possibility of easy adoption of the proposed GP (in aspects of the geographical localization and availability of sources for the recycling, etc.) indicates high flexibility and adoptability, considering the economic, social and cultural environment.**

**Long and short terms context impacts on GP feasibility and transferability in terms of economic, political, social and cultural environment, involvement of special competencies and skills.**

**The critical aspects affecting the long and the short terms impacts are special competencies and skills in the area of redesigning the UHMWPE fibrous materials.**

**This risk will be reduced by the transfer of the competencies in subjected terms via education and training support.**



# RESET

## Interreg Europe



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# Thank you!

Many thanks to:

- prof. Andrzej Gałęski & dr inż. Artur Różański (CBMiM PAN);
- dr hab. Jan Wojtysiak & mgr inż. Andrzej Moraczewski  
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Państwowego Instytut Badawczy – Łódź)  
for the scientific support !

Questions welcome



*Project smedia*