A Strategic Roadmap for Manufacturing

Haydn Thompson, THHINK Ltd.
Road4FAME in a nutshell

Roadmapping and technology transfer experts and manufacturing IT experts

Road4FAME Core Group

Road4FAME Consortium

Road4FAME Experts Group
Road4FAME in a nutshell

Selected experts and representatives from industry and the FoF roadmapping ecosystem for:

- Strategic advice
- Link to expertise
- Validation of project results
- Multiplicators for project results
Road4FAME in a nutshell

Around 100 experts and representatives from industry and academia for:

- participation in expert consultations / interviews
- participation in workshops
- involvement in internal deliverable development and review process
Approach of Road4FAME

**Push Perspective**
- Screening for novel concepts
- Identification of R&D Challenges
- Identification of Enablers
- Validation step

**Pull Perspective**
- Socio-economic Analysis
- Identification of Needs and Requirements
- Translation into ICT / architecture requirements
- Validation step

**Core Roadmapping Process**
- Roadmapping Workshops
- Roadmap for IT Architectures and Services in Manufacturing
- R&I Strategy Documents
- Business Models
How it used to be.....

Raw Materials → Fabrication → Assembly → Customer

Automation
Today

- Synthetic Materials
- Raw Materials
- Recycled Materials

Additive Manufacturing

Fabrication

Software
High proportion of product

Assembly
Batch Size -> 1!

Customer

- Technology effect and a networking effect
- Virtual Manufacturing Network
- Joint R&D

Customisation, Delivery, Green products

Tools for the extended enterprise
- EDI PLM
- KPIs (Quality, Cost, Delivery)
- Kanban
- Cradle-to-Grave Tracking
- Sensors
- Supply Chain
- Virtual Prototyping
- Energy
- M2M
- Flexible and Adaptive Tooling

Reducing scrap

Recycling
Recommendations for Research Priorities
Research Recommendations

- **Scalable Cyber-Physical System architectures** for adaptive and smart manufacturing
- **Real-time** data acquisition and analysis
- **Network-centric communication and collaboration** between players, humans and systems across the entire value chain
- **ICT platform** for advanced supply chain decision support
- Modelling of **virtual enterprises**

**Cross-cutting** challenges

- Interoperability / Standards
- Semantic mechanisms
- Socio-technical issues
- Training and education
- Cyber security
Recommendations

Integration
- **Integration approaches for existing ICT systems and information** (tackling the “wild garden”)
- **Integration of new smart components** (e.g. new improved low cost, miniaturised sensors) for data collection, analysis and visualisation
- Development/promotion of **standardization and reference ICT architectures** as well as **interoperability** and harmonization of different interfaces

Data and Information
- **Unified engineering exchange of data** considering provenance, accuracy, contextual awareness and semantic content of unstructured data
- **Big Data capture** (live streaming for situational awareness), storage (event driven databases) and analysis (data mining – ideally in real time)
- **Distributed processing algorithms** for data and systems in real time supported by resilient “industrial strength” **cloud computing** for the plant floor
- **Visualisation techniques** and specifically context-aware responsive visualisation of data
- **Decision support systems** to reduce operator load

Machine Learning and Adaptive Systems to Enable Flexible and Adaptive Manufacturing
- Environments and infrastructures for **machine learning, self-adapting and reconfigurable** manufacturing
- **Intra-and inter- machine communication standards**
- **Human-centric adaptive interfaces** to enhance usability

Multidisciplinary Modelling
- **Modelling** of factories, information modelling and work domain modelling of socio-technological systems

Security and Privacy
- **Robust Machine-to-Machine** (M2M) security protocols that guarantee operational safety and reliability
- Affordable **security for privacy**, especially within manufacturing supply networks

Demonstrators & Education
- To convince the conservative manufacturing sector of the cost/benefits of new ICT architectures and services
- **Education initiatives** and training materials to increase awareness
**Recommendations**

**Reference Architectures / Open Architectures**
Many projects have generated reference architectures. These could be transformed into open architectures, which can be either implemented or further developed or adapted by other projects to improve them further.

**System and Information Integration Architectures**
System and Information Integration Architectures are becoming increasingly important due to the growing heterogeneity, amount of information and system components available and they need to be developed to cope with this challenge.

**Data Capture, Storage and Analysis**
Technology to capture, store and analyze data is advancing from a technical standpoint, but specifically from a methodical and legal side further developments are needed to enable efficient sensible data and information handling, enabling business models and innovation, while protecting individuals and companies.
Recommendations

Data and Information Visualization
Visualization techniques and specifically context-aware responsive visualization of data which is a major pre-condition for efficient decision support systems. Human-centric adaptive interfaces and context-centric display of only crucial information to enhance usability.

Security
Research in security strategy, protocols and tools for companies and standards to protect the networked and distributed manufacturing systems would be necessary to ensure balance between security cost and benefits to an organization.

Confidentiality
Confidentiality and know-how protection throughout the network of increasingly larger interconnected networks is essential. Therefore technological evolution of authorization, authentication and encryption mechanisms, as well as the establishment of trust among network participants, to cope with this scenario is recommended.
Recommendations

**Flexible and Adaptable Manufacturing**
Self-adapting, resilient and reconfigurable manufacturing environments need to be facilitated by standardization of intra- and inter-machine communication. Wireless technologies, context awareness, human-interaction and self-learning (e.g. for production configuration) mechanisms, etc. can significantly contribute to efficiency improvements of the (re-) configuration, ramp-up, and optimization.

**New or Improved low-cost, miniaturized smart sensors**
Sensors need to become cheaper, smarter, smaller and more energy efficient, to enable new applications that until now were not possible or viable enough due to technological and economic restraints.

**CPPS - Cyber-Physical Production Systems**
CP(P)S concepts need to be further evaluated and implemented. Certain standards such as self-description, integration/interface, intercommunication and orchestration need to be developed for on platform and system level.
Recommendations

New Algorithms
The development of easy to use algorithms for analysis, and real time prediction needs to both address various manufacturing enterprises and also be time and resource efficient and cost effective, especially for SMEs. It also has to incorporate knowledge from other domains, where necessary. Furthermore, the algorithms should be able to be executed in a distributed manner to ensure their applicability in manufacturing environments.

Modelling
The development of smarter and better information and domain models can provide not only design details but also greater predictive capacity in order to reduce physical prototyping needs or construction of pilot plants. Simulations, virtual reality, tacit knowledge modelling and User eXperience (UX) of mathematical modelling potentially supports problem solving, decision support and rapid prototyping.
Recommendations for Innovation Strategies
## Innovation Strategies

<table>
<thead>
<tr>
<th>Innovation Catalyst</th>
<th>Useful For</th>
</tr>
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<tbody>
<tr>
<td>Competence Centres</td>
<td>To promote interaction between researchers, industry, and the public sector, in research topics that promote economic growth</td>
</tr>
<tr>
<td>Regional initiatives</td>
<td>To improve competitiveness of SMEs both locally and internationally, help with qualification, upgrading and diversification, test solutions, and carry out early implementations</td>
</tr>
<tr>
<td>Innovation Clusters</td>
<td>To bring together industry and researchers to address specific topics or markets with the aim of creating critical mass in technological areas</td>
</tr>
<tr>
<td>National initiatives</td>
<td>National initiatives can be used to engage with larger companies accelerating research and technology in areas that are considered to be nationally important, develop a technological lead and provide a strategic vision of the future</td>
</tr>
<tr>
<td>Flagship Projects</td>
<td>Flagship research and development projects can be used to support strategically and scientifically defined objectives and engage with many project partners across Europe</td>
</tr>
<tr>
<td>Platform Building</td>
<td>Platforms can be used to create ecosystems or support specific sectors. They need to be interoperable, modular, and scalable with open and standardised interfaces. Critically for uptake they need to be affordable both from applications development and operation perspectives, with clear and easy understandable business cases</td>
</tr>
<tr>
<td>Demonstrators and Large Scale Pilots</td>
<td>Demonstrators and Large Scale Pilots are seen as essential to show potential adopters, both SMEs and large companies, that new technologies and solutions can be exploited in the real world.</td>
</tr>
<tr>
<td>Entrepreneurship</td>
<td>Education via an entrepreneurship programme eliminates the fear of failure and provides guidance and support for patenting, commercialization of R&amp;D results and business start-up.</td>
</tr>
<tr>
<td>Education and Skills</td>
<td>To promote holistic digital skills and training support at all levels, disseminating best practice and experience to re-skill and up-skill the workforce.</td>
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</tbody>
</table>
Business Models and Business Opportunities
### Business Model Categorisations (100 models in 10 categories)

#### Conventional
- Manufacturer Model - Selling Direct
- Merchant Model
- Advertising Model
- Information Model
- Brokerage Model
- Premium branding or limited availability
- Licensing, franchising
- Open innovation (platforms)
- Hire & leasing
- Razor and Blades Model
- Cutting out the Middlemen
- Bricks and Clicks
- Subscription Business Model
- Value Added Reseller
- Fee in, free out – charge first client only
- All in one business model
- Loyalty business model
- Monopolistic business model
- Premium business model
- Professional Open Source Business Model
- Machine supplier

#### Green/Sustainable
- Repair, the Circular Economy, and Collaborative Consumption
- Sustainability and value
- Low carbon manufacturing or solutions
- Cradle-to-cradle
- Reuse, recycle, re-manufacture
- Take back management
- Move from non-renewable to renewable sources
- Green chemistry
- Solar and wind-power based energy innovations
- Chemical Management Services (CMS)
- Dematerialised services
- Collaborative consumption
- Incentivised return & re-use
- Collection of used products
- Blue economy
- Choice editing by retailers

#### Networking
- The ‘Density Principle’
- Acting as a network entity
- Interaction and indirect capabilities
- Trans-sector collaboration
- Network Architecture Business Model
- Sharing assets (shared ownership and collaborative consumption)
- Crowd sourcing or funding
- Collaborative approaches (sourcing, production, lobbying)
- Collective Business Model
- Online Auction Business Model
- Network Effects Business Model
- Organisational form

#### Technology Based
- Additive manufacturing
- Information Technology (IT) - Infinite Bandwidth/Zero Latency
- General-purpose technologies
- Increased functionality
- Biomimicry

#### Socially Aware
- Ethical trade (fair trade)
- Resource stewardship
- Biodiversity protection
- Responsible product distribution or promotion
- Slow fashion
- Slow Manufacturing
- Product longevity
- Long life
- Radical transparency about eco or societal impacts
- Consumer care - promote consumer health and well-being
- Not for profit
- Social and biodiversity regeneration initiatives (‘net positive’)
- Hybrid businesses, social enterprise (for profit)
- Alternative ownership: cooperative, mutual, (farmers) collectives
- Home based, flexible working
- Extended producer responsibility
- Frugal business (products for low income markets)
- Localisation
- Bring your own device

#### Knowledge
- Continuous innovation
- Creating value through information
- Incubators and entrepreneur support models
- Consumer education (models); communication and awareness
- Solution provider

#### Aftermarket/Product Service
- Asset management
- Product Service System
- Product-oriented PSS - maintenance, extended warrantee
- Use oriented PSS - rental, lease, shared
- Result oriented - pay per use
- Online Services Model
- Demand management (including cap & trade)
- Maintenance partner
- Performance partner
- Value partner

#### Efficient Manufacturing
- Lean manufacturing
- De-materialisation (of products or packaging)
- Use excess capacity
- Industrial symbiosis

#### Customisation
- Made to order
- Personalisation, Identity, Provenance
- Mass customisation
- Design and Innovation Service
- Fabless manufacturing
- Frugal innovation

#### Economic
- Build-operate-transfer (BOT)
- "Patient or slow capital" collaborations

#### Road 4 FAME
- "Value in the value chain - co-production, co-innovation, co-creation, co-marketing"
<table>
<thead>
<tr>
<th>Business Opportunities</th>
<th>Service</th>
<th>Status of Uptake</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge</td>
<td>R&amp;D</td>
<td>Current</td>
</tr>
<tr>
<td></td>
<td>Technology Consulting</td>
<td>Current</td>
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<tr>
<td></td>
<td>Innovation</td>
<td>Current</td>
</tr>
<tr>
<td></td>
<td>Retired Engineer Service</td>
<td>New</td>
</tr>
<tr>
<td>Design</td>
<td>Product Customisation</td>
<td>New</td>
</tr>
<tr>
<td>Integration</td>
<td>ICT Tailoring</td>
<td>Current Increasing</td>
</tr>
<tr>
<td></td>
<td>ICT Integration</td>
<td>Current Increasing</td>
</tr>
<tr>
<td>ICT Maintenance</td>
<td>ICT Support</td>
<td>Current</td>
</tr>
<tr>
<td>Supply Chain</td>
<td>Management &amp; Optimisation</td>
<td>New</td>
</tr>
<tr>
<td></td>
<td>Sourcing Raw Materials</td>
<td>New</td>
</tr>
<tr>
<td></td>
<td>Traceability/Tracking of components</td>
<td>New</td>
</tr>
<tr>
<td></td>
<td>CO2 Calculation</td>
<td>New</td>
</tr>
<tr>
<td></td>
<td>Data broker between stakeholders</td>
<td>New</td>
</tr>
<tr>
<td>Simulation</td>
<td>Factory</td>
<td>Current Increasing</td>
</tr>
<tr>
<td></td>
<td>Product</td>
<td>Current Increasing</td>
</tr>
<tr>
<td>Financial</td>
<td>Accounting</td>
<td>Current</td>
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<tr>
<td></td>
<td>Product Costing</td>
<td>Current</td>
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<tr>
<td>Customer Focus</td>
<td>CRM</td>
<td>Current</td>
</tr>
<tr>
<td>External Computing</td>
<td>Data Centre</td>
<td>New Increasing</td>
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<tr>
<td></td>
<td>Cloud Computing</td>
<td>New Increasing</td>
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<tr>
<td>Monitoring</td>
<td>Wireless Sensors</td>
<td>New Increasing</td>
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<tr>
<td></td>
<td>Big Data Management</td>
<td>New Increasing</td>
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<tr>
<td></td>
<td>Data Mining</td>
<td>New Increasing</td>
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<tr>
<td></td>
<td>Visualisation</td>
<td>Current Increasing</td>
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<td></td>
<td>Decision Support</td>
<td>Current Increasing</td>
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<tr>
<td></td>
<td>Energy Management/Brokering</td>
<td>New Increasing</td>
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<tr>
<td>Product Services</td>
<td>Servitization Support</td>
<td>New</td>
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<td></td>
<td>Aftermarket Support</td>
<td>New</td>
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<tr>
<td></td>
<td>Available Hours Contracts</td>
<td>New Increasing</td>
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<td></td>
<td>&quot;Photocoper&quot; Contracts</td>
<td>New Increasing</td>
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<td></td>
<td>Monitoring Own Equipment -maintenance</td>
<td>New</td>
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<td></td>
<td>Providing process optimisation</td>
<td>New</td>
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<td></td>
<td>(based on own machine monitoring)</td>
<td>New</td>
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<tr>
<td>Sales</td>
<td>Marketing</td>
<td>Current</td>
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<td></td>
<td>Demand Prediction</td>
<td>Current</td>
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<tr>
<td></td>
<td>Customer Polling</td>
<td>Current</td>
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<tr>
<td></td>
<td>Renting Showcase Products</td>
<td>New</td>
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<tr>
<td>Spare Capacity</td>
<td>Renting Machinery</td>
<td>New</td>
</tr>
<tr>
<td>Security</td>
<td>Providing guaranteed security</td>
<td>New</td>
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<tr>
<td></td>
<td>Attending trade for SMEs</td>
<td>New</td>
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</tbody>
</table>
Transversal View Converging Themes
Conclusion for Converging Themes

- Seamless **integration** of systems and components
- Acquisition and use of big data in real time & handling of complexity
- Visualisation, virtualisation, situational awareness, **decision support**
- **Interoperability**, standardisation, **reference architectures** and tools
- **Platforms** (organisational, technological, operational, customer,..)

- Security, privacy, trust
- Regulatory issues, IP
- Demonstrations, living labs
- Business models
- De-fragmentation, cross-fertilisation
- Raise awareness & education
- Commitment of large industries
- Enhance involvement of SMEs
Thank you