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Fill the Gaps between A&A Industrial Practice and Academic Research via Product Lifecycle Management

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Approached by the Journal of Aeronautics & Aerospace Engineering, it is my great honour to provide my personal observations in the active research field of aeronautics and aerospace (A&A) engineering in relation to industrial development. The products in the A&A industry have become more complex than ever before as have the related processes, such the A380 airplane [1]. The product lifecycle management concept has been broadly addressed as a holistic approach to connect product and process modeling domains so that the industry can take full advantage of engineering informatics supported by modern information and computer technologies (ICTs). However, there are many gaps between A&A industrial practice and academic research.

Firstly, in most academic research, topics are addressed piece by piece, focusing on specific issues that are manageable for individual researchers, such as weight and structure optimization [2] and the related processes [3]. With all due respect to the specific contributions by academic researchers working in the field, coherent research programs addressing the broad systematic and thematic problems of the industry are rare in academic research, if they exist at all. Given the complexity of modern A&A product development, the approach of industrial development is always a dynamic system engineering challenge, from the beginning of conceptualization, to design phases, prototyping, testing and analysis, enhancement in the iterations of development cycles, and market or engineering change management [4,5]. Therefore, piecemeal research inherited as a university-centric research effort has become less and less relevant for solving the thematic problems faced by the A&A industry. Focusing on the framework of thematic research initiatives, the A&A industry should cluster academic researchers under a modularly structured program and work with the relevant governments, learning from the energy sector such as the oil sands development in Canada [6], to work out some science and technology research programs with the appropriate size of scope and depth of collaboration. A large-scale, industry-wide, well-structured, coherent, heavy weight manpower and investment commitment and approach are required.

Secondly, broadband synthetic collaboration among research teams has to be built into the genes of any such large-scale research program in order to achieve the required development cycle time. The author would like to distinguish the synthetic collaboration aforementioned from the typical research collaboration commonly observed in academic circles, where collaboration is limited to information-sharing, citing original works, and manpower exchange. Semantic networking and unified modeling across a giant chain of A&A research domains is necessary as suggested in Bajaj [7,8] although those studies seem trivial from the angle of industrial recognition in contrast to the A&A product launch [9]. Such synthetic collaboration must be organized and managed with an interoperable system at a variety of granularities of information focuses and navigation. Interfacial definitions for the relations between pieces of technological results should be specified, evaluated, and dynamically validated, throughout the collaboration lifecycle.

Thirdly, all the processes across the industry spectrum should be streamlined and integrated with product lifecycle management tools, from marketing to conceptualization, design, manufacturing, maintenance (including overhaul), and redevelopment. Product engineering processes should enable engineers referencing the existing and the ongoing up-stream or down-stream information and knowledge transparently, as in the cases shown in Jagtap's recent work [10]. An example study for the civil aircraft repair and overhaul supply chain can also be found in Lee [11]. It should be appreciated that inter-corporation and intra-supply chain networks of collaboration can be the most important organizational frameworks for the A&A industry due to the nature of current Intellectual Property (IP) licensing and management schemes for engineering [12]. Certain federation approaches for access to IP-related documents across the industry have to be worked out in order to enable borderless virtual collaboration with some meaningful sustainability for the proposed PLM approach [13].

Certain thematic research topics are of strategic importance and warrant some global collaboration programs between the industry and academicians.

1. New material modeling, testing, analysis, manufacturing process optimization, and design tools. It has been accepted by the industry that many new materials have the unique advantage of "weight-strength-flexibility" trade-off in high-end A&A applications, such as ceramic composites [14]. However, the fundamental material mechanics, reliability modeling and assurance design methods, forming and joining processes and overall computer-aided design and analysis tools are not available to general users.

2. Associative product and process ICT support systems for complex, sustained, and dynamic product lifecycle management. With the current practice, product development is not associated with processes of manufacturing and after-sales support. Given the high performance, high-complexity, and high-reliability requirement for A&A products, "design for dynamic behaviours" is in high demand and the current engineering design tools are largely ineffective; separate development efforts are imposed even though the long term interoperability between systems is not well considered [15]. The required applications include design for performance of working or extreme conditions, seamlessly integrated design and analysis solutions, associated manufacturing processes, tooling and cost engineering, and

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a "need-based" information-supporting environment for value chain partners.

3. New generation semantics standardization study for the information interoperability in multi-faceted engineering information system development. Semantic modeling is essential for the interoperability of sub-systems in a complex and flexible engineering environment. One of the consequent capabilities expected from semantic modeling is to specify each module's "Plug-and-Play" interfaces of a complex product within the aspects of concurrent design and process engineering, from marketing, design, manufacturing, resources planning, sales support, customer support, and maintenance, to recycling. The desired in-depth semantic modeling can be complicated, such as human-automation interactions [16]. User-defined features have to be allowed in those massive ERP-like ICT systems that will have enormous scalability because they are highly unified, and yet can be fully customized as to user interfaces for all the processes; NASA has been exploring a virtual testing bed in this line [17]. For user customization, any programming requirement, such as the current Application Programming Interface (API)-based development, will be in the past; rather, friendly and descriptive logical language will drive the user requirement supported by intensive semantic modeling and terminology standardization.

With the above points in mind, the author would like to conclude this editorial with the following comments. The A&A industry and the related academic research are not interfaced well enough to support healthy development cycles. Research circles should appreciate the demand of industry for coherent answers to address those "big-picture" thematic problems instead of just the "micro" solutions currently on offer. Formulating systematic research programs with highly specified interfaces among research "nuggets" is the promising approach of governments, corporations, and clusters of small and medium-sized players. Researchers, on the other hand, should identify their works with the "local coordinates" of a bigger picture driven by the industry and should constantly adapt their individual solutions such that they are always ready to be integrated seamlessly with other collaborative solutions. The interfacing edge definition of the puzzle, i.e. semantics standardization, is the imperative research task for both the industry and the related academic research circle.

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