FENET Industry Requirements

Aerospace Industry Sector

Version 1.2 – 20 November 2001

EC 5th Framework FENET Thematic Network for Finite Element / Engineering Analysis
Detailed info at http://www.fe-net.org

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Revision record

Version	*Date*	*Description*
1.0	16-Oct-2001	Initial release
1.1	9-Nov-2001	Update following review by T. Henriksen (ESA D/TOS-MCS)
1.2	20-Nov-2001	Updated after presentation at FENET 1st Annual Meeting in Wiesbaden

1 Introduction

1.1 General

This note contains the first release of the industry requirements for the Aerospace Industry Sector. It was derived by merging the initial requirements presented by ESA and EADS at the first FENET Network Steering Committee meeting 27-28 September 2001. In addition a maturity level was associated with each requirement using the definitions given in section 1.2.

The requirements are grouped according to the four FENET Technical Themes:
- Durability & Life Extension
- Product & System Optimisation
- Multi Physics & Analysis Technology
- Education & Dissemination

This is a 'living' document, that will be regularly updated as the specified requirements and engineering analysis methods and tools evolve.

1.2 Specifying the maturity of industry sector requirements, methods and tools

Apart from identifying and defining the engineering analysis requirements and their associated methods and tools, it is also essential to indicate the functional and industrial maturity of each. The maturity level is necessary for FENET members (and other interested readers) to assess whether a given method / tool at the specified level of maturity could be of interest for application in their own domain or to get an idea about how much additional development would be needed before the method / tool would suit their needs. The objective is to provide a means to distinguish as much as possible in a rational way between methods and tools ranging from ‘a wishlist of ideas and concepts’ to fully validated, robust, integrated CAE applications.

As a scale to define different levels of maturity we propose to use the so-called **Technology Readiness Level (TRL)** specification, which was originally defined by NASA to characterise space technology research and development items. This characterisation has also been adopted by ESA in its technology research and development planning. It provides an easy to understand distinction in nine different levels of technology readiness.

In order to make the TRL definitions usable in the context of FENET, an adapted set of definitions suitable for engineering analysis methods and tools has been formulated. See Table 1 below.

Table 1 – Definition of Technology Readiness Levels (TRLs)[1]

TRL	*Original definition for space programmes (NASA, ESA)*	*Definition for engineering analysis method / tool (adapted for FENET)*	*Life cycle stage*
TRL 1	Basic principles observed and reported	Basic principles observed and reported	Basic Technology Research
TRL 2	Technology concept and/or application formulated	Concept and application of method / algorithm(s) formulated	Research to Prove Feasibility
TRL 3	Analytical and experimental critical function and/or characteristic proof of concept	Proof of concept demonstrated for critical aspects of method / algorithm(s)	
TRL 4	Component and/or breadboard validation in laboratory environment	Method / prototype tool validated on simple representative test cases	Technology Development
TRL 5	Component and/or breadboard validation in relevant environment	Method / prototype tool validated on comprehensive representative test cases	Technology Demonstration
TRL 6	System/subsystem model or prototype demonstration in a relevant environment (ground or space)	Method / prototype tool demonstrated on representative 'real world' analysis problems – implemented functionality complete – performance / interfacing solved in principle	
TRL 7	System prototype demonstration in a space environment	Method / 'beta-release' tool validated on representative 'real world' analysis problems – implemented functionality, performance and interfacing complete	Method / Tool Development
TRL 8	Actual system completed and "flight qualified" through test and demonstration (ground or space)	Robust method / tool, routinely used in industrial product development environments – with adequate software problem handling, distribution, user documentation and support	Method / Tool Operation
TRL 9	Actual system "flight proven" through successful mission operations	TRL 8, plus method / tool fully integrated in the industrial product development processes	

[1] The left two columns are as defined in NASA's Technology Plan, Appendix B, and used in ESA's Technology R&D planning. See http://technologyplan.nasa.gov/default.cfm?id=AppB for full details. The third and fourth columns are adapted for engineering analysis methods and tools, for use in the FENET context.

2 Industry Requirements for the Aerospace Industry Sector

2.1 Durability & Life Extension

ID	*Modelling / analysis requirement*	*TRL*	*Remark(s)*
2.1.1	Failure mechanisms of fibre reinforced composite materials	7	
2.1.2	Fracture mechanics / fracture control	8	
2.1.3	Crack propagation and residual strength	8	More than 15 years of co-operation between ESA and NASA for the development of relevant methodologies and numerical tools, e.g. NASGRO and ESACRACK
2.1.4	Damage / damage tolerance	3-8	Extension to non-metallic materials and elastic-plastic conditions needed
2.1.5	Support maintenance and upgrades of legacy aircraft - life cycle >30 years -	6	Needs for data integrity and standardisation, long term archiving
2.1.6	Assessment of structural damage: dents, de-laminations, etc.	7	
2.1.7	Determination of stress-intensity-factors (SIF)	7	FE and BE
2.1.8	P-element method	8	Tools PROBE, StressCheck and NASTRAN used at ESA
2.1.9	Linking FEM and BEM	6	Fluid-structure interaction
2.1.10	Integration of tools for Structural Analysis and Life (Cycle) Analysis, in particular w.r.t. geometry, loads, material property databases, probabilistic analysis	4	

2.2 Product & System Optimisation

ID	*Modelling / analysis requirement*	*TRL*	*Remark(s)*
2.2.1	Multi-level process integration	5	
2.2.2	Integration of engineering analysis into design and development processes	5	Objectives are: More effective, shorter engineering analysis cycles. Support collaborative, concurrent, multi-disciplinary engineering
2.2.3	Model data management and configuration control	5	Provided by some PDM tools, but integration with CAE tools need to be improved
2.2.4	Automation of the structural analysis process	5	
2.2.5	Extended enterprise interoperability	5	
2.2.6	Simulation of manufacturing processes: cold working, interference fits, sheet metal forming	7	
2.2.7	Non-linear dynamic analysis for impact, crash, bird-strike, etc.	8	
2.2.8	Non-linear static analysis of metallic structures with accurate failure prediction	6	
2.2.9	Widespread industrial application of structural optimisation	5	
2.2.10	Use of legacy models and data	5	Need for better data integrity, open standards, configuration control, meta-data
2.2.11	CAD-to-CAE model idealisation	5	Need for idealisation benchmarks?
2.2.12	CAE-to-CAD modification feedback	2	
2.2.13	Support heterogeneous mix of tools / computing platforms	5	Need for more open standards
2.2.14	Use of open standards: e.g. ISO/STEP (AP209, ...), W3C/XML, OMG, NCSA/HDF5, …	4-8	Maturity level depends on used standard and application domain
2.2.15	Catalogues of parts/components with FEM representation	3	Applied in pilot projects Needs further development
2.2.16	Capture design/analysis experience	4	Large documented corpus of experience available at ESA and aircraft industry. Some courses given.
2.2.17	Enable access to captured design/analysis experience	3	Link with knowledge management.

2.3 Multi Physics & Analysis Technology

ID	*Modelling / analysis requirement*	*TRL*	*Remark(s)*
2.3.1	Integration of engineering analysis into design and development processes	5	Objectives are: More effective, shorter engineering analysis cycles. Support collaborative, concurrent, multi-disciplinary engineering
2.3.2	Coupled analyses for aircraft structure / aero-elastics / aerodynamics: acoustics, ditching, etc.	5	
2.3.3	Thermo-mechanical interaction and thermo-elastic deformation	8	E.g. lightweight aircraft structures, spacecraft payloads, mounting interfaces, re-entry vehicles
2.3.4	Structure – aero-thermodynamics interaction	8	
2.3.5	Structure – aero-acoustics / compressible fluids interaction	7	E.g. Ariane-payload coupled loads analysis tool, Xenon tanks, …
2.3.6	Structure – aero-thermodynamics - chemical interaction	6	E.g. aero-engines, launcher and spacecraft propulsion, ablative heat shields, re-entry vehicles
2.3.7	Highly non-linear problems	6	E.g. tank bladder collapse, large inflatable structures
2.3.8	Structure - optics interaction	6	E.g. spacecraft payload instruments, aircraft awareness/reconnaissance sensors
2.3.9	Structure / micro-wave antenna interaction	4	
2.3.10	Structure / kinematics / control logic	7	E.g. Deployment of large flexible structures (antenna) with control-loop feedback, robots
2.3.11	Probabilistic Analysis Approach	5	Tools ASKA RV, NASTRAN RV, ST-ORM used at ESA
2.3.12	Dynamic (near-)real-time mathematical model test correlation/update	4	
2.3.13	Support for advanced materials, w.r.t. - physical representation - failure criteria (composites, ceramics) - links to design tools (ESAComp) - micro-mechanics / multi-scale	4	

2.4 Education & Dissemination

ID	*Modelling / analysis requirement*	*TRL*	*Remark(s)*
2.4.1	Increase the quality of FE models	N.A.	
2.4.2	Means to evaluate FE model quality	6	
2.4.3	Guidelines / standards for creating system simulation models	4	Standards / best practices under development under ECSS.
2.4.4	Standard for Mathematical Models	4	Standards / best practices under development under ECSS.

2.5 Acronyms & Abbreviations

AP	(STEP) Application Protocol
BE	Boundary Element
BEM	Boundary Element Model
CAD	Computer Aided Design
CAE	Computer Aided Engineering
ECSS	European Cooperation for Space Standardization (www.estec.esa.int/ecss)
ESA	European Space Agency
FE	Finite Element
FEA	Finite Element Analysis
FEM	Finite Element Model
HDF	Hierarchical Data Format (hdf.ncsa.uiuc.edu)
N.A.	Not Applicable
NASA	National Aeronautics and Space Administration (USA)
NCSA	National Center for Supercomputing Applications (USA)
OMG	Object Management Group (www.omg.org)
RV	Reliability Version
STEP	STandard for the Exchange of Product model data = Casual name for ISO 10303 (www.nist.gov/sc4)
TRL	Technology Readiness Level
XML	eXtensible Markup Language (www.w3.org/xml)
W3C	World Wide Web Consortium (www.w3.org)