First Order Estimate of AP209E2 Modularization and Extension Tasks

Rev 1.0

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These estimates assume that Keith is working on this with support from Darla Nettles. The times would be significantly higher if either would not be able to be the primary producers as significant knowledge of the AP and the modularization creation and publication process is assumed.

The following are the Units of Functionality of AP209E1. Many of these are covered by module work to date, these are marked by an '*', and those that will have to be extended with '**".

- **activity_control;
- *advanced_boundary_representation;
- analysis_report;
- *assembly;
- **authorization;
- composite_constituent_representation;
- *effectivity;
- *end_item_identification;
- *faceted_boundary_representation;
- fea_model;
- fe_analysis_control;
- fe_analysis_results;
- *manifold_surface_with_topology;
- material;
- *non_topological_surface_and_wireframe;
- part_composite_constituents;
- **part_identification;
- part_laminate_table;
- **part_shape;
- *wireframe_with_topology;
- zone_composite_constituents_and_their_representation.

Of the 21 UoFs, 12 have modular work to date, with 4 of the 12 requiring some extension, mostly to deal with the duality of Design Discipline Product Definition (DDPD) and the Analysis Discipline Product Definition (ADPD), and the delineation of Nominal, Idealized, and Analysis Shapes.

The remaining 9 UoFs are unique to AP209 and will have to be modularized. Of these 9, 5 are concerned with composite structural definition and representation. The remaining 4 are concerned with Finite Element Analysis, with a fifth, material, shared with composites.

Extensions to Existing Modules

The extensions tasks will include:

- adding text definitions;
- modifying existing EXPRESS-G diagrams;
- generating new ARM EXPRESS;
- generating new MIM EXPRESS.

activity_control

Extensions to apply to APDPD and other AP209 ARM objects, 8 hours.

authorization

Extensions to apply to APDPD and other AP209 ARM objects, 8 hours.

part_identification

Extensions to apply to APDPD and other AP209 ARM objects, add analysis specific ARM objects, 24 hours.

- analysis;
- analysis_design_version_relationship;
- analysis_discipline_product_definition;
- analysis_version;
- design_discipline_product_definition;
- design_material;
- file;
- mass_measure.

part_shape

Extension to apply to the delineation of Nominal, Idealized, and Analysis Shapes, 24 hours.

- analysis_shape;
- idealized_analysis_shape;
- node_shape;
- nominal_design_shape;
- shape;
- shape_aspect.

Composite Structural Definition and Representation Modularization

The Modularization tasks will include:

- creating text definitions for ARM and MIM – virtually all will be copied from E1 document (1 hour);
- transcribing mapping table (1 hour);
- creating EXPRESS-G diagrams (2 hours);
- generating new ARM EXPRESS (0.1 hour);
- generating new MIM EXPRESS (0.1 hour).

This results in a rough ROM of 4.2 hours per Application Object (AO). As there are approximately 80 unique AOs this results in an estimate of 336 hours.

composite_constituent_representation

- angle_measure;
- beveled_sheet_representation;
- boundary_curve_representation;
- composite_sheet_representation;
- constituent_shape_representation;
- curve;
- direction;
- face_based_sheet_representation;
- filament_laminate_shape;
- flat_pattern_ply_shape;
- geometric_model_representation;
- geometric_sheet_representation;
- geometry_element;
- laid_ply_shape;
- length_measure;
- location;
- loop;
- ply_shape;
- projected_ply_shape;
- surface;
- surface_ply_shape;
- three_d_geometry_set;
- view_ply_shape.

material

- additional_design_information;
- anisotropic_material;
- design_specification;
- direction;
- discontinuous_fiber_assembly;
- environment;
- filament_assembly;
- isotropic_material;
- material_direction;
- material_property;
- material_specification;
- measure_value;

— process_specification;
— specification;
— stock_core;
— stock_material;
— surface_finish_specification;
— usage_constraint.

part_composite_constituents
— composite_assembly;
— constituent_part;
— curve;
— direction;
— filament_laminate;
— length_measure;
— mass_measure;
— ply;
— ply_laminate;
— ply_orientation_angle;
— ply_piece;
— point;
— point_and_vector;
— point_path;
— processed_core.

part_laminate_table
— composite_assembly_sequence_definition;
— composite_assembly_table;
— direction;
— laminate_table;
— location;
— part_laminate_table;
— ply_laminate_sequence_definition;
— ply_laminate_table;
— reinforcement_orientation_basis;
— surface;
— surface_with_direction.

zone_composite_constituents_and_their_representation
— angle_measure;
— boundary_representation;
— curve;
— direction;
— draped_orientation_angle;
— edge_zone_shape;
— laid_orientation_angle;
— laminate_table;
— length_measure;
— location;
— loop;
— percentage;
— percentage_laminate_table;
— percentage_ply;

— ply_orientation_angle;
— point;
— point_and_vector;
— point_path;
— point_zone_shape;
— reinforcement_orientation_basis;
— smeared_material;
— surface;
— surface_with_direction;
— thickness_laminate_table;
— zone_structural_makeup;
— zone_structural_makeup_shape_representation.

Finite Element Analysis Modularization

The Modularization tasks will include:

- creating text definitions for ARM and MIM – virtually all will be copied from E1 document (1 hour);
- transcribing mapping table (1 hour)
- creating EXPRESS-G diagrams (2 hours);
- generating new ARM EXPRESS (0.1 hour);
- generating new MIM EXPRESS (0.1 hour).

This results in a rough ROM of 4.2 hours per Application Object (AO). As there are approximately 60 AOs this results in an estimate of 252 hours.

analysis_report

- analysis_report_representation;
- graphical_representation;
- tabular_representation.

fea_model

- curve_cross_section;
- curve_element;
- curve_property;
- curve_section_properties;
- damping_matrix;
- directionally_explicit_element;
- element;
- element_description;
- element_property_geometric_relationship;
- element_shape_aspect;
- element_shape_relationship;
- environment;
- explicit_element;
- fea_material_definition;
- fea_material_property;
- fea_material_specification;
- fea_model;
- fea_model_description;
- geometric_model_representation;
- geometry_element;
- group;
- group_relationship;
- mass_matrix;
- material_property;
- material_specification;
- matrix;
- nodal_results_coordinate_system;
- node;
- node_description;
- node_shape_relationship;
- point_element;
- point_model;
- specification;
- stiffness_matrix;

— substructure_element;
— substructure_node_relationship;
— surface_element;
— surface_property;
— surface_thickness;
— volume_element.

fe_analysis_control
— analysis_message;
— calculated_state;
— constraint;
— element_field_variable_definition;
— element_nodal_freedom_actions;
— fe_analysis;
— fe_analysis_control_step;
— fe_analysis_state;
— fe_analysis_state_definition;
— linear_constraint_equation;
— linear_constraint_equation_value;
— linearly_superimposed_state;
— modes_and_frequencies_control_step;
— nodal_degree_of_freedom_reduction;
— nodal_freedom_definitions;
— output_request_state;
— single_point_constraint;
— single_point_constraint_values;
— specified_state;
— static_control_step.

fe_analysis_results
— analysis_message;
— calculated_state;
— constraint;
— element_field_variable_definition;
— element_nodal_freedom_actions;
— fe_analysis_results;
— fe_analysis_results_step;
— fe_analysis_state;
— fe_analysis_state_definition;
— linear_constraint_equation;
— linear_constraint_equation_value;
— linearly_superimposed_state;
— modes_and_frequencies_results_step;
— nodal_degree_of_freedom_reduction;
— nodal_freedom_definitions;
— output_request_state;
— single_point_constraint;
— single_point_constraint_values;
— specified_state;
— static_results_step.

material

— additional_design_information;
— anisotropic_material;
— design_specification;
— direction;
— discontinuous_fiber_assembly;
— environment;
— filament_assembly;
— isotropic_material;
— material_direction;
— material_property;
— material_specification;
— measure_value;
— process_specification;
— specification;
— stock_core;
— stock_material;
— surface_finish_specification;
— usage_constraint.

Implementation and AP Module Creation

Roughly half of the Implementation Modules will be taken from AP203E2. However, some will require some additional modules that will be created in the tasks above covering modifying existing modules. The remaining implementation modules will be for composites, materials, and Finite Element Analysis.

The plan at the present time is for all of the new AP209 Implementation Modules to roughly follow the UoFs of AP209. This will result in significantly larger modules than many produced to date, however there is no pressing business/sharing requirement for finer granularity particularly as the components of these UoFs need to be used as monolithic blocks due to the structure of the Integrated Resources and the application domain. Given this, the new Implementation modules for AP209 will be:

- analysis_report;
- composite_constituent_representation;
- fea_model;
- fe_analysis_control;
- fe_analysis_results;
- material;
- part_composite_constituents;
- part_shape;
- zone_composite_constituents_and_their_representation.

The Implementation Modularization tasks will include:

- creating text definitions for ARM and MIM (2 hours);
- creating EXPRESS-G diagrams and context diagrams (4 hours);
- generating new ARM EXPRESS (1 hour);
- generating new MIM EXPRESS (1 hour).

This results in a rough ROM of 8 hours per Implementation Module As there are approximately 9 Implementation Modules this results in an estimate of 72 hours. In addition the AP level module should take about 10 hours.

Additional AP209E2 Capabilities

There are two major areas where the STEP Integrated Resources have been extended as part of the ongoing Engineering Analysis Core Model (EACM) and Computational Fluid Dynamics efforts. The first provides capabilities to represent continuous and discrete fields to be used as properties and/or state information. The second provided a generic structured and unstructured grid representation capability that will support a large number of non-FEA computational disciplines such as Fluid Dynamics and Heat Transfer.

Finally, a major area of complaint against AP209 is the non-coverage of Nonlinear Analyses. Though the AP and the underlying Integrated Resources of STEP were designed to easily be extended to nonlinear, this was not done due to a time and cost constraint. This would be a fairly straight-forward and valuable addition to AP209.

EACM Fields and Properties

The EACM field and property extensions are quite small in scope and would add Application Objects to all of the FEA UoFs. These capabilities are supported by the 50 series Parts of STEP, and integrated with Part 104 by Part 107. All of these documents are at DIS or above thus providing minimal added risk to this task. As there are roughly 30 or so ARM/MIM objects to be documented an estimate would be:

- creating text definitions for ARM and MIM (2 hours);
- creating mapping table (2 hours)
- creating EXPRESS-G diagrams (2 hours);
- generating new ARM EXPRESS (0.1 hour);
- generating new MIM EXPRESS (0.1 hour).

This results in a rough ROM of 6.2 hours per Application Object (AO). As there are approximately 30 AOs this results in an estimate of 186 hours.

General Structured and Unstructured Grids and Analyses

The second capability addition would require substantially more time investment – probably on the order of the modularization of the FEM portion of AP209, about 200 hours. However there is a possibility that some help from David Leal and other personnel from the UK BSI/NAFEMS CAD/FE working group can apply resources to create these modules.

Nonlinear Analyses

The primary task is extending and/or generalizing the field representations in Part 104 and AP209 to represent nonlinear components. The other areas are element types and nonlinear boundary conditions and loads. A small update to Part 104 may also be required. The general structured and unstructured grids and analysis capabilities of STEP would need no further update as they now adequately cover nonlinear analyses. A very rough guess for this addition would be 150 hours. However there is a possibility that some help from David Leal and other personnel from the UK BSI/NAFEMS CAD/FE working group can apply resources to create these modules.

Summary and Estimate Rollup

Primary Objective	
Modify existing modules	64
Composites modules	336
FEA modules	252
EACM modules	186
Implementation and AP modules	82
Total	**920 hours**
Stretch Objective	
Structured/Unstructured	
Grids and Analyses	200
Nonlinear Analyses	150
Previous Total	920
Total	**1270 hours**