ISO 15926-2:2003-12 (E)

Industrial automation systems and integration - Integration of life-cycle data for process plants including oil and gas production facilities - Part 2: Data model

Contents

Page

1 Scope 1

2 Normative references 2

3 Terms, definitions and abbreviations 2
3.1 Terms and definitions 2
3.2 Abbreviations 4

4 Fundamental concepts and assumptions 4
4.1 Conceptual data model 4
4.2 Data model design 5
4.3 System identifiers 5
4.4 Record management information 5
4.5 Documentation conventions 6
4.5.1 Entity and attribute definitions 6
4.5.2 Diagrams 6
4.5.2.1 Space-time maps 6
4.5.2.2 Model diagrams 7
4.5.2.3 Instance diagrams 7
4.6 Data model concepts 8
4.6.1 Thing 8
4.6.2 Possible individual 9
4.6.3 Class 9
4.6.4 Relationship 9
4.6.5 Multidimensional object 10
4.7 Possible individual 10
4.7.1 Composition of possible individual 11
4.7.2 Temporal part of individual 12
4.7.3 Connection of individual 13
4.7.4 Temporal sequence of individual 15
4.7.5 Subtypes of individual 16
4.7.6 Actual individual 16
4.7.7 Lifecycle stage of individual 17
4.7.8 Whole life individual 18
4.7.9 Arranged individual 19
4.7.9.1 Arrangement of individual 19
4.7.10 Event and point in time 21
4.7.11 Period in time 24
4.7.12 Physical object 26
4.7.13 Materialised physical object 26
4.7.14 Functional physical object 27
4.7.15 Spatial location 28
4.7.16 Stream 28
4.7.17 Activity 29
4.7.18 Approval 32
4.8 Class 33
4.8.1 Classification 33
4.8.2 Specialization 35
4.8.3 Types of class 36
4.8.3.1 Class of individual 36
4.8.3.2 Class of class 37

4.8.3.3 Class of relationship ... 37
4.8.4 Class of individual ... 41
4.8.4.1 Class of arranged individual ... 42
4.8.4.2 Representation ... 47
4.8.4.3 Property ... 56
4.8.4.4 Status and class of status ... 64
4.8.4.5 Shape and dimension ... 65
4.8.4.6 Class of event and point in time ... 71
4.8.4.7 Class of period in time ... 72
4.8.4.8 Role and domain ... 73
4.8.4.9 Class of activity ... 75
4.8.4.10 Class of class of individual ... 77
4.8.5 Numbers ... 78
4.8.5.1 Arithmetic number ... 78
4.8.5.2 Class of number ... 79
4.9 Functional mapping ... 82
4.10 Other user defined relationships ... 85
4.10.1 Other relationship ... 85
4.10.2 Class of relationship with signature ... 86
4.10.3 Cardinality constraints ... 88
4.10.4 Assymetric other relationship classes ... 88

5 Lifecycle integration schema ... 90
5.1 Introduction ... 90
5.2 Schema definition ... 90
5.2.1 Things ... 90
5.2.1.1 abstract_object ... 91
5.2.1.2 thing ... 91
5.2.2 Classes ... 92
5.2.2.1 class ... 93
5.2.2.2 class_of_abstract_object ... 94
5.2.2.3 classification ... 94
5.2.2.4 specialization ... 95
5.2.3 Classes of class ... 96
5.2.3.1 class_of_class ... 96
5.2.3.2 class_of_classification ... 97
5.2.3.3 class_of_property_space ... 97
5.2.3.4 class_of_specialization ... 98
5.2.4 Multidimensional objects ... 98
5.2.4.1 class_of_multidimensional_object ... 99
5.2.4.2 multidimensional_object ... 100
5.2.5 Numbers ... 101
5.2.5.1 arithmetic_number ... 102
5.2.5.2 boundary_of_number_space ... 103
5.2.5.3 class_of_number ... 103
5.2.5.4 enumerated_number_set ... 103
5.2.5.5 integer_number ... 104
5.2.5.6 lower_bound_of_number_range ... 104
5.2.5.7 multidimensional_number ... 104
5.2.5.8 multidimensional_number_space ... 104
5.2.5.9 number_range ... 105
5.2.5.10 number_space ... 105
5.2.5.11 real_number ... 105
5.2.5.12 upper_bound_of_number_range ... 105
5.2.6 Possible individuals ... 106
5.2.6.1 actual_individual ... 107
5.2.6.2 arranged_individual ... 108
5.2.6.3 arrangement_of_individual ... 108
5.2.6.4 assembly_of_individual ... 109
5.2.6.5 composition_of_individual ... 109
5.2.6.6 feature_whole_part ... 109
5.2.6.7 functional_physical_object ... 110

5.2.6.8 materialized_physical_object 110
5.2.6.9 period_in_time 110
5.2.6.10 physical_object 111
5.2.6.11 possible_individual 111
5.2.6.12 spatial_location 112
5.2.6.13 stream 112
5.2.6.14 temporal_whole_part 112
5.2.6.15 whole_life_individual 113
5.2.7 Classes of individual 113
5.2.7.1 class_of_arrangement_of_individual 114
5.2.7.2 class_of_assembly_of_individual 115
5.2.7.3 class_of_class_of_composition 115
5.2.7.4 class_of_class_of_individual 116
5.2.7.5 class_of_composition_of_individual 116
5.2.7.6 class_of_event 116
5.2.7.7 class_of_feature_whole_part 117
5.2.7.8 class_of_individual 117
5.2.7.9 class_of_period_in_time 117
5.2.7.10 class_of_point_in_time 118
5.2.7.11 class_of_status 118
5.2.7.12 class_of_temporal_whole_part 118
5.2.7.13 status 118
5.2.8 Classes of arranged individual 119
5.2.8.1 class_of_arranged_individual 120
5.2.8.2 class_of_atom 120
5.2.8.3 class_of_biological_matter 121
5.2.8.4 class_of_composite_material 121
5.2.8.5 class_of_compound 121
5.2.8.6 class_of_feature 121
5.2.8.7 class_of_functional_object 122
5.2.8.8 class_of_inanimate_physical_object 122
5.2.8.9 class_of_information_object 122
5.2.8.10 class_of_information_presentation 123
5.2.8.11 class_of_molecule 123
5.2.8.12 class_of_organism 123
5.2.8.13 class_of_organization 123
5.2.8.14 class_of_particulate_material 124
5.2.8.15 class_of_person 124
5.2.8.16 class_of_sub_atomic_particle 124
5.2.8.17 crystalline_structure 124
5.2.8.18 phase 125
5.2.9 Activities and events 125
5.2.9.1 activity 126
5.2.9.2 beginning 127
5.2.9.3 cause_of_event 127
5.2.9.4 ending 127
5.2.9.5 event 128
5.2.9.6 involvement_by_reference 128
5.2.9.7 participation 128
5.2.9.8 point_in_time 129
5.2.9.9 recognition 129
5.2.9.10 temporal_bounding 130
5.2.10 Classes of activity 130
5.2.10.1 class_of_activity 131
5.2.10.2 class_of_cause_of_beginning_of_class_of_individual 132
5.2.10.3 class_of_cause_of_ending_of_class_of_individual 132
5.2.10.4 class_of_involvement_by_reference 133
5.2.10.5 class_of_participation 133
5.2.10.6 class_of_recognition 134
5.2.11 Relationships 134
5.2.11.1 other_relationship 135
5.2.11.2 relationship 136

5.2.12 Classes of relationship ... 137
5.2.12.1 class_of_assertion ... 137
5.2.12.2 class_of_relationship ... 138
5.2.12.3 class_of_relationship_with_related_end_1 ... 139
5.2.12.4 class_of_relationship_with_related_end_2 ... 139
5.2.13 Roles and domains ... 140
5.2.13.1 cardinality ... 140
5.2.13.2 class_of_relationship_with_signature ... 141
5.2.13.3 participating_role_and_domain ... 142
5.2.13.4 role ... 142
5.2.13.5 role_and_domain ... 142
5.2.13.6 specialization_by_domain ... 142
5.2.13.7 specialization_by_role ... 143
5.2.14 Classes of class of relationship ... 143
5.2.14.1 class_of_class_of_relationship ... 144
5.2.14.2 class_of_class_of_relationship_with_signature ... 145
5.2.14.3 class_of_scale ... 145
5.2.15 Functions ... 145
5.2.15.1 class_of_functional_mapping ... 146
5.2.15.2 class_of_isomorphic_functional_mapping ... 147
5.2.15.3 functional_mapping ... 147
5.2.16 Representations of things ... 148
5.2.16.1 definition ... 148
5.2.16.2 description ... 149
5.2.16.3 identification ... 149
5.2.16.4 representation_of_thing ... 149
5.2.16.5 responsibility_for_representation ... 150
5.2.16.6 usage_of_representation ... 150
5.2.17 Classes of representation ... 151
5.2.17.1 class_of_definition ... 152
5.2.17.2 class_of_description ... 153
5.2.17.3 class_of_identification ... 153
5.2.17.4 class_of_information_representation ... 153
5.2.17.5 class_of_representation_of_thing ... 154
5.2.17.6 class_of_representation_translation ... 154
5.2.17.7 class_of_responsibility_for_representation ... 155
5.2.17.8 class_of_usage_of_representation ... 155
5.2.18 EXPRESS and UTC representations ... 156
5.2.18.1 EXPRESS_Boolean ... 156
5.2.18.2 EXPRESS_binary ... 157
5.2.18.3 EXPRESS_integer ... 157
5.2.18.4 EXPRESS_logical ... 158
5.2.18.5 EXPRESS_real ... 158
5.2.18.6 EXPRESS_string ... 159
5.2.18.7 class_of_EXPRESS_information_representation ... 159
5.2.18.8 representation_of_Gregorian_date_and_UTC_time ... 160
5.2.19 Classes of class of representation ... 161
5.2.19.1 class_of_class_of_definition ... 162
5.2.19.2 class_of_class_of_description ... 163
5.2.19.3 class_of_class_of_identification ... 163
5.2.19.4 class_of_class_of_information_representation ... 163
5.2.19.5 class_of_class_of_representation ... 163
5.2.19.6 class_of_class_of_representation_translation ... 164
5.2.19.7 class_of_class_of_responsibility_for_representation ... 164
5.2.19.8 class_of_class_of_usage_of_representation ... 165
5.2.19.9 document_definition ... 165
5.2.19.10 language ... 166
5.2.19.11 representation_form ... 166
5.2.20 Namespaces ... 166
5.2.20.1 class_of_left_namespace ... 167
5.2.20.2 class_of_namespace ... 167
5.2.20.3 class_of_right_namespace ... 168

5.2.20.4 left_namespace 168
5.2.20.5 namespace 168
5.2.20.6 right_namespace 169
5.2.21 Connections 169
5.2.21.1 class_of_connection_of_individual 170
5.2.21.2 class_of_direct_connection 171
5.2.21.3 class_of_indirect_connection 171
5.2.21.4 class_of_individual_used_in_connection 172
5.2.21.5 connection_of_individual 172
5.2.21.6 direct_connection 173
5.2.21.7 indirect_connection 173
5.2.21.8 individual_used_in_connection 173
5.2.22 Relative locations and sequences 174
5.2.22.1 class_of_containment_of_individual 174
5.2.22.2 class_of_relative_location 175
5.2.22.3 class_of_temporal_sequence 175
5.2.22.4 containment_of_individual 176
5.2.22.5 relative_location 176
5.2.22.6 temporal_sequence 177
5.2.23 Lifecycle stages and approvals 177
5.2.23.1 approval 178
5.2.23.2 class_of_approval 179
5.2.23.3 class_of_approval_by_status 179
5.2.23.4 class_of_lifecycle_stage 180
5.2.23.5 lifecycle_stage 180
5.2.24 Possible and intended roles 180
5.2.24.1 class_of_intended_role_and_domain 181
5.2.24.2 class_of_possible_role_and_domain 182
5.2.24.3 intended_role_and_domain 182
5.2.24.4 possible_role_and_domain 183
5.2.25 Set operations 183
5.2.25.1 difference_of_set_of_class 184
5.2.25.2 enumerated_set_of_class 185
5.2.25.3 intersection_of_set_of_class 185
5.2.25.4 union_of_set_of_class 185
5.2.26 Properties 186
5.2.26.1 class_of_indirect_property 187
5.2.26.2 comparison_of_property 188
5.2.26.3 indirect_property 188
5.2.26.4 multidimensional_property 189
5.2.26.5 property 189
5.2.26.6 property_quantification 189
5.2.27 Classes of property 190
5.2.27.1 boundary_of_property_space 191
5.2.27.2 class_of_property 192
5.2.27.3 enumerated_property_set 192
5.2.27.4 lower_bound_of_property_range 192
5.2.27.5 multidimensional_property_space 193
5.2.27.6 property_range 193
5.2.27.7 property_space 193
5.2.27.8 single_property_dimension 194
5.2.27.9 upper_bound_of_property_range 194
5.2.28 Scale conversions 194
5.2.28.1 class_of_scale_conversion 195
5.2.28.2 coordinate_system 196
5.2.28.3 multidimensional_scale 196
5.2.28.4 scale 196
5.2.29 Shapes 197
5.2.29.1 class_of_dimension_for_shape 197
5.2.29.2 class_of_shape 198
5.2.29.3 class_of_shape_dimension 198
5.2.29.4 dimension_of_individual 198

5.2.29.5 dimension_of_shape 199
5.2.29.6 individual_dimension 199
5.2.29.7 property_for_shape_dimension 200
5.2.29.8 property_space_for_class_of_shape_dimension 200
5.2.29.9 shape 200
5.2.29.10 shape_dimension 201
5.2.29.11 specialization_of_individual_dimension_from_property 201

Annex A (normative) Information object registration 202

Annex B (informative) Computer interpretable listings 203

Annex C (informative) Use of ISO 10303-11 EXPRESS 204

Annex D (informative) Some notes on set theory in ISO15926 205

Annex E (informative) An analysis of the uses and meanings of associations 209

Bibliography 218

Index 219

Figures Figure 1 -- Three level architecture 4

Figure 2 -- Space-time map 6

Figure 3 -- Model diagram 7

Figure 4 -- Instance diagram notation 7

Figure 5 -- Example diagram notation 8

Figure 6 -- Part of the model subtype/supertype hierarchy 9

Figure 7 -- Possible individual as a space-time extension 10

Figure 8 -- Instance diagram for possible individual #1234 11

Figure 9 -- Composition of individual relationships 11

Figure 10 -- Intersecting space-time extensions 11

Figure 11 -- Instance diagram for composition of individual 12

Figure 12 -- Temporal part 12

Figure 13 -- Temporal whole part relationships 12

Figure 14 -- Temporal part #9012 of #1234 13

Figure 15 -- Connected space-time extensions 13

Figure 16 -- Connection of individual 14

Figure 17 -- Shaft seal direct connection 14

Figure 18 -- Individual used in connection 14

Figure 19 -- Shaft crankcase indirect connection 15

Figure 20 -- Sequence of space-time extensions 15

Figure 21 -- Temporal sequence 16

Figure 22 -- James Watt and the Battle of Hastings 16

Figure 23 -- Subtypes of possible_individual 16

Figure 24 -- Possible and actual individuals 17

Figure 25 -- Instance diagram of possible and actual individuals 17

Figure 26 -- Lifecycle relationship 17

Figure 27 -- The pump required by XYZ Co 18

Figure 28 -- Space-time map of a piece of plastic 18

Figure 29 -- Plastic piece and cup as whole life individuals 19

Figure 30 -- Arranged individual 19

Figure 31 -- Arrangement of individual 20

Figure 32 -- Assembly of pump 20

Figure 33 -- Corrosion features 21

Figure 34 -- Event space-time extensions 21

Figure 35 -- Event boundary space-time map 22

Figure 36 -- Model diagram of event 22

Figure 37 -- Instance diagram of the ending of the stationary state 23

Figure 38 -- Instance diagram of the pig space-time trajectory 23

Figure 39 -- Point in time extensions 23

Figure 40 -- Model diagram of Event 24

Figure 41 -- Instance diagram of the actual point in time described as Figure 42 -- Instance diagram of time of the stationary state 24

Figure 43 -- Period in time space-time extension 25

Figure 44 -- Period in time entity type 25

Figure 45 -- Space-time map for a period of time and its bounding points in time 25

Figure 46 -- Period in time 10:26 to 11:09 26

Figure 47 -- Types of physical object 26

Figure 48 -- Material continuity space-time map 27

Figure 49 -- Pump temporal parts 27

Figure 50 -- Function physical object P101 space-time map 28

Figure 51 -- Instance diagram for pump 1 installed as P101 28

Figure 52 -- Activity participation 29

Figure 53 -- Cup forming activity 29

Figure 54 -- Instance diagram of cup forming activity 30

Figure 55 -- Cause of event model 30

Figure 56 -- Cup beginning caused by a cup pressing run 30

Figure 57 -- Involvement by reference 31

Figure 58 -- Recognition by activity 31

Figure 59 -- Ship classification activity 31

10am 17 November 2002 UTC 24

Figure 60 -- Approval 32

Figure 61 -- Approval of cup raw material 32

Figure 62 -- Model of classification relationship 33

Figure 63 -- Classification of pump 34

Figure 64 -- Classification of operating pump 34

Figure 65 -- Operating temporal part of a pump 34

Figure 66 -- Specialization relationship 35

Figure 67 -- Pump specialization 35

Figure 68 -- Transitive specialization 36

Figure 69 -- Subtypes of class 36

Figure 70 -- Colour class of class 37

Figure 71 -- Class of connection of individual 37

Figure 72 -- Seal connected to Type A drive shaft 38

Figure 73 -- Cardinality constraints for classes of relationship 39

Figure 74 -- Type A drive shafts may connect to up to two seals 39

Figure 75 -- An asymmetric class of relationship 40

Figure 76 -- Constraining a symmetric class of relationship 40

Figure 77 -- Seals connected to a particular shaft 41

Figure 78 -- Subtypes of class_of_individual 41

Figure 79 -- Class of composition of individual and subtypes 42

Figure 80 -- Composition of centrifugal pumps 42

Figure 81 -- Classes of arranged individual for material structure 43

Figure 82 -- Levels of arrangement of for water 44

Figure 83 -- Arrangement of H2O molecules 44

Figure 84 -- Complex classes of arranged individual 45

Figure 85 -- Class of inanimate physical object 45

Figure 86 -- Information classes of arranged individual 46

Figure 87 -- Class of information object 47

Figure 88 -- Representation of thing 47

Figure 89 -- Class of representation of thing 48

Figure 90 -- Representation of #3578 48

Figure 91 -- Identification, description and definition 49

Figure 92 -- Class of Identification, description and definition 49

Figure 93 -- Pump identification 50

Figure 94 -- Use and control of representation 50

Figure 95 -- Use and control of class of representation 51

Figure 96 -- XYZ Co product identifiers 51

Figure 97 -- Class of class of information representation 52

Figure 98 -- Part 21 representation 52

Figure 99 -- Class of class of usage and responsibility of representation 53

Figure 100 -- XYZ Co pump data sheets 53

Figure 101 -- Class of namespace 54

Figure 102 -- Vessel V1 nozzle namespace 54

Figure 103 -- Vessel V1 nozzle N1 identification 55

Figure 104 -- P101 P&ID URL 55

Figure 105 -- Property and class of property 56

Figure 106 -- Temperature property 56

Figure 107 -- Property quantification 57

Figure 108 -- Scale 57

Figure 109 -- Quantification of temperature 21.0 deg C 58

Figure 110 -- Model of indirect property 58

Figure 111 -- Choke valve pressure drop 59

Figure 112 -- Maximum allowable working pressure 59

Figure 113 -- Property comparison 59

Figure 114 -- Comparison of two properties 60

Figure 115 -- Property spaces 60

Figure 116 -- Temperature range 20 - 40 C 61

Figure 117 -- Type A seal working temperature range 61

Figure 118 -- Multidimensional property model 62

Figure 119 -- A pump flow characteristic 62

Figure 120 -- Pump flow characteristic [Q,H]1 63

Figure 121 -- Type 24 pump head flow characteristic 63

Figure 122 -- Coordinate system model 64

Figure 123 -- Coordinate system CS 21 64

Figure 124 -- Status and class of status 65

Figure 125 -- Surface condition statuses 65

Figure 126 -- Dimension of individual 66

Figure 127 -- Width of my table 66

Figure 128 -- Properties of individual dimension 66

Figure 129 -- My table width of 520 mm 67

Figure 130 -- Shape and class of shape 67

Figure 131 -- Rectangle shapes 67

Figure 132 -- Dimension of shape 68

Figure 133 -- 10cm diameter circle 68

Figure 134 -- Property for shape dimension 69

Figure 135 -- Diameters of 10 cm length 69

Figure 136 -- Class of shape dimension 70

Figure 137 -- Diameters of circles 70

Figure 138 -- Shape dimension property classes 71

Figure 139 -- Diameter lengths 71

Figure 140 -- Class of event and point in time 71

Figure 141 -- Midnight takeoff events 72

Figure 142 -- Class of period in time 72

Figure 143 -- July follows June 72

Figure 144 -- Role and domain 73

Figure 145 -- Controller person role and domain 73

Figure 146 -- Intended and possible role and domain 74

Figure 147 -- Intended performer role for pumps 75

Figure 148 -- Participating role and domain 75

Figure 149 -- Class of activity 76

Figure 150 -- Fluid measurement activity using type 167 instrument 76

Figure 151 -- Fluid pressure measurement activity 77

Figure 152 -- Fluid pressure measurement 77

Figure 153 -- Class of class of individual 78

Figure 154 -- Arithmetic number 78

Figure 155 -- Representation of real number 79

Figure 156 -- Multidimensional number 79

Figure 157 -- Class of number 79

Figure 158 -- Enumerated number set 80

Figure 159 -- Bounds of number range 80

Figure 160 -- Number range 5.2 to 9.3 81

Figure 161 -- R3 real number space 81

Figure 162 -- Complex numbers 82

Figure 163 -- Functional mapping 82

Figure 164 -- X2 functional mapping 83

Figure 165 -- Pressure difference functional mapping 83

Figure 166 -- Functional mapping subtypes 84

Figure 167 -- Venn diagrams of classes A,B,C, I, U, and D 84

Figure 168 -- Intersection, union and difference of classes A, B, C 85

Figure 169 -- Other relationship 85

Figure 170 -- Ownership relationship 86

Figure 171 -- Class of relationship with signature 86

Figure 172 -- Ownership class of relationship with signature 87

Figure 173 -- Insertion of individual 87

Figure 174 -- 6 of M8 bolts 88

Figure 175 -- Asymmetric class of relationship with signature 89

Figure 176 -- Bloggs made products 89

Figure 177 -- lifecycle_integration_schema EXPRESS-G diagram 1 of 29 91

Figure 178 -- lifecycle_integration_schema EXPRESS-G diagram 2 of 29 93

Figure 179 -- lifecycle_integration_schema EXPRESS-G diagram 3 of 29 96

Figure 180 -- lifecycle_integration_schema EXPRESS-G diagram 4 of 29 99

Figure 181 -- lifecycle_integration_schema EXPRESS-G diagram 5 of 29 102

Figure 182 -- lifecycle_integration_schema EXPRESS-G diagram 6 of 29 107

Figure 183 -- lifecycle_integration_schema EXPRESS-G diagram 7 of 29 114

Figure 184 -- lifecycle_integration_schema EXPRESS-G diagram 8 of 29 119

Figure 185 -- lifecycle_integration_schema EXPRESS-G diagram 9 of 29 126

Figure 186 -- lifecycle_integration_schema EXPRESS-G diagram 10 of 29 131

Figure 187 -- lifecycle_integration_schema EXPRESS-G diagram 11 of 29 135

Figure 188 -- lifecycle_integration_schema EXPRESS-G diagram 12 of 29 137

Figure 189 -- lifecycle_integration_schema EXPRESS-G diagram 13 of 29 140

Figure 190 -- lifecycle_integration_schema EXPRESS-G diagram 14 of 29 144

Figure 191 -- lifecycle_integration_schema EXPRESS-G diagram 15 of 29 146

Figure 192 -- lifecycle_integration_schema EXPRESS-G diagram 16 of 29 148

Figure 193 -- lifecycle_integration_schema EXPRESS-G diagram 17 of 29 152

Figure 194 -- lifecycle_integration_schema EXPRESS-G diagram 18 of 29 156

Figure 195 -- lifecycle_integration_schema EXPRESS-G diagram 19 of 29 162

Figure 196 -- lifecycle_integration_schema EXPRESS-G diagram 20 of 29 167

Figure 197 -- lifecycle_integration_schema EXPRESS-G diagram 21 of 29 170

Figure 198 -- lifecycle_integration_schema EXPRESS-G diagram 22 of 29 174

Figure 199 -- lifecycle_integration_schema EXPRESS-G diagram 23 of 29 178

Figure 200 -- lifecycle_integration_schema EXPRESS-G diagram 24 of 29 181

Figure 201 -- lifecycle_integration_schema EXPRESS-G diagram 25 of 29 184

Figure 202 -- lifecycle_integration_schema EXPRESS-G diagram 26 of 29 187

Figure 203 -- lifecycle_integration_schema EXPRESS-G diagram 27 of 29 191

Figure 204 -- lifecycle_integration_schema EXPRESS-G diagram 28 of 29 195

Figure 205 -- lifecycle_integration_schema EXPRESS-G diagram 29 of 29 197

Figure D.1 -- Single level sets 206

Figure D.2 -- An example of hierarchical sets 206

Figure D.3 -- An example of well-founded sets 207

Figure D.4 -- An example of non-well-founded sets 208

Figure E.1 -- Moving from a snapshot model to one using associations 210

Figure E.2 -- Space-time map 210

Figure E.3 -- An example of a classification association 211

Figure E.4 -- A space-time map for classification of an individual 211

Figure E.5 -- Classification using states 212

Figure E.6 -- Association between two individuals 212

Figure E.7 -- A space-time map for composition 213

Figure E.8 -- Composition using states 213

Figure E.9 -- Coincident individuals 214

Figure E.10 -- Space-time map for coincident individuals 214

Figure E.11 -- Coincident individuals using states 215

Figure E.12 -- A relationship between two classes 215

Figure E.13 -- Analysis of a relationship between two classes 216

Figure E.14 -- A class of relationship 216

Figure E.15 -- Analysis of a class of relationship 217