

Generic Approach to Architecture Optimization

IBM Research - Haifa

Henry Broodney, Lev Greenberg, Michael Masin, Dolev Dotan

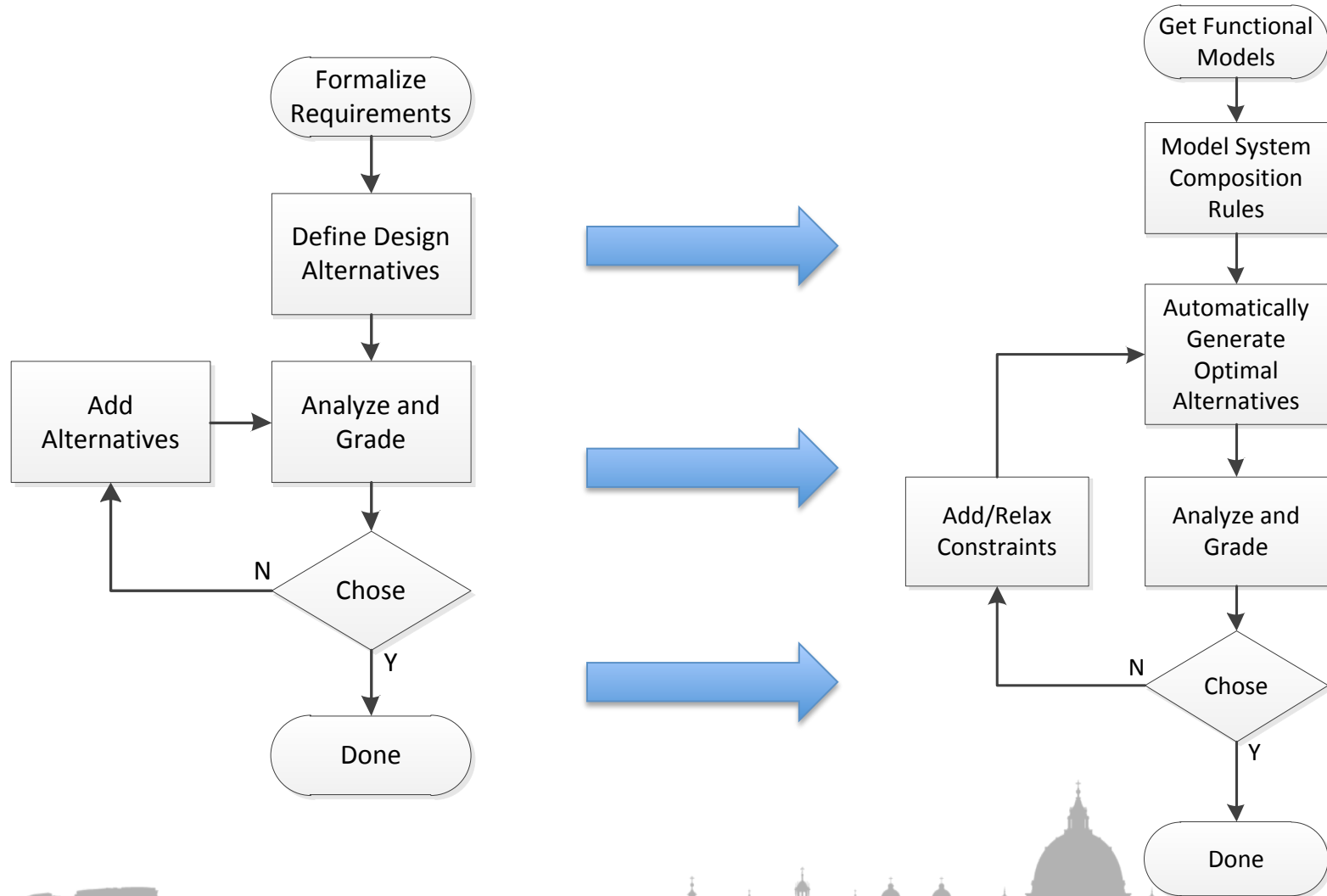


Architectural Design - Problems and Remedies



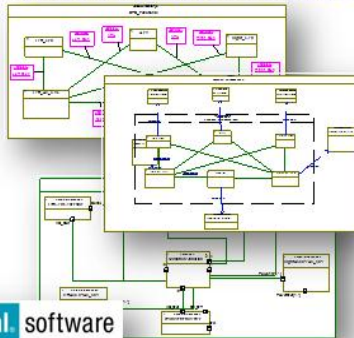
- Key concerns:
 - System Complexity is increasing – manual decisions no longer possible
 - Design Space Exploration tools today – Excel and Visio
 - Optimization requires a math expert to work with the Systems Engineer
 - Lots of information is lost in the interaction
 - Tedious and manual management of such processes
- Solution approach:
 - Allow the Systems Engineer to formally express the system composition rules and constraints
 - Automatically generate the optimization code from the model
 - Visualize results
 - Management tool orchestration and collaboration

Architectural design flow – now and next



Architecture Optimization Workbench Concept

1. Describe system through different SysML views, including design alternatives, constraints and goals



Rational software
Rhapsody

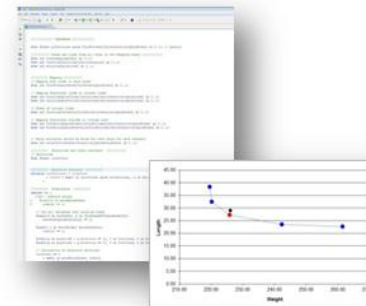
2. Derived Data Schema for Input and output structures

id	name	guid	variants
1	Junction	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	Cat.Junction
3	Relay	GUID8feb223d-5bc6-40d6-b173-46b5ff3d7e58	Cat.Relay

id	name	guid	type id	type name	variants	date from	to
2	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	2	IPAcceptor	no.Variant		
3	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	3	IPGenerator	no.Variant		
4	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	4	IPAcceptor	no.Variant		
5	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	5	IPGenerator	no.Variant		
6	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	6	IPAcceptor	no.Variant		
7	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	7	IPGenerator	no.Variant		
8	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	8	IPAcceptor	no.Variant		
9	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	9	IPGenerator	no.Variant		
10	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	10	IPAcceptor	no.Variant		
11	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	11	IPGenerator	no.Variant		
12	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	12	IPAcceptor	no.Variant		
13	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	13	IPGenerator	no.Variant		
14	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	14	IPAcceptor	no.Variant		
15	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	15	IPGenerator	no.Variant		
16	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	16	IPAcceptor	no.Variant		
17	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	17	IPGenerator	no.Variant		
18	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	18	IPAcceptor	no.Variant		
19	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	19	IPGenerator	no.Variant		
20	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	20	IPAcceptor	no.Variant		
21	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	21	IPGenerator	no.Variant		
22	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	22	IPAcceptor	no.Variant		
23	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	23	IPGenerator	no.Variant		
24	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	24	IPAcceptor	no.Variant		
25	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	25	IPGenerator	no.Variant		
26	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	26	IPAcceptor	no.Variant		
27	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	27	IPGenerator	no.Variant		
28	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	28	IPAcceptor	no.Variant		
29	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	29	IPGenerator	no.Variant		
30	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	30	IPAcceptor	no.Variant		
31	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	31	IPGenerator	no.Variant		
32	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	32	IPAcceptor	no.Variant		
33	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	33	IPGenerator	no.Variant		
34	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	34	IPAcceptor	no.Variant		
35	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	35	IPGenerator	no.Variant		
36	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	36	IPAcceptor	no.Variant		
37	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	37	IPGenerator	no.Variant		
38	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	38	IPAcceptor	no.Variant		
39	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	39	IPGenerator	no.Variant		
40	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	40	IPAcceptor	no.Variant		
41	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	41	IPGenerator	no.Variant		
42	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	42	IPAcceptor	no.Variant		
43	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	43	IPGenerator	no.Variant		
44	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	44	IPAcceptor	no.Variant		
45	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	45	IPGenerator	no.Variant		
46	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	46	IPAcceptor	no.Variant		
47	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	47	IPGenerator	no.Variant		
48	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	48	IPAcceptor	no.Variant		
49	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	49	IPGenerator	no.Variant		
50	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	50	IPAcceptor	no.Variant		
51	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	51	IPGenerator	no.Variant		
52	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	52	IPAcceptor	no.Variant		
53	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	53	IPGenerator	no.Variant		
54	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	54	IPAcceptor	no.Variant		
55	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	55	IPGenerator	no.Variant		
56	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	56	IPAcceptor	no.Variant		
57	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	57	IPGenerator	no.Variant		
58	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	58	IPAcceptor	no.Variant		
59	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	59	IPGenerator	no.Variant		
60	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	60	IPAcceptor	no.Variant		
61	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	61	IPGenerator	no.Variant		
62	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	62	IPAcceptor	no.Variant		
63	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	63	IPGenerator	no.Variant		
64	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	64	IPAcceptor	no.Variant		
65	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	65	IPGenerator	no.Variant		
66	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	66	IPAcceptor	no.Variant		
67	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	67	IPGenerator	no.Variant		
68	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	68	IPAcceptor	no.Variant		
69	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	69	IPGenerator	no.Variant		
70	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	70	IPAcceptor	no.Variant		
71	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	71	IPGenerator	no.Variant		
72	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	72	IPAcceptor	no.Variant		
73	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	73	IPGenerator	no.Variant		
74	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	74	IPAcceptor	no.Variant		
75	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	75	IPGenerator	no.Variant		
76	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	76	IPAcceptor	no.Variant		
77	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	77	IPGenerator	no.Variant		
78	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	78	IPAcceptor	no.Variant		
79	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	79	IPGenerator	no.Variant		
80	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	80	IPAcceptor	no.Variant		
81	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	81	IPGenerator	no.Variant		
82	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	82	IPAcceptor	no.Variant		
83	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	83	IPGenerator	no.Variant		
84	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	84	IPAcceptor	no.Variant		
85	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	85	IPGenerator	no.Variant		
86	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	86	IPAcceptor	no.Variant		
87	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	87	IPGenerator	no.Variant		
88	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	88	IPAcceptor	no.Variant		
89	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	89	IPGenerator	no.Variant		
90	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	90	IPAcceptor	no.Variant		
91	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	91	IPGenerator	no.Variant		
92	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	92	IPAcceptor	no.Variant		
93	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	93	IPGenerator	no.Variant		
94	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	94	IPAcceptor	no.Variant		
95	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	95	IPGenerator	no.Variant		
96	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	96	IPAcceptor	no.Variant		
97	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	97	IPGenerator	no.Variant		
98	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	98	IPAcceptor	no.Variant		
99	IPGenerator	GUIDe1eb1581-c487-4be2-9fd6-8ce56e53b2ea	99	IPGenerator	no.Variant		
100	IPAcceptor	GUID9e129-9a8-4001-886a-e155a1a132a2	100	IPAcceptor	no.Variant		

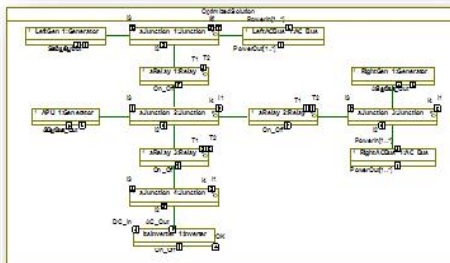
Architecture
Optimization
through Design
Space Exploration
iterations

3. Automatic translation(via an interchange format) into Optimization solver



IBM
ILOG
CPLEX
Studio

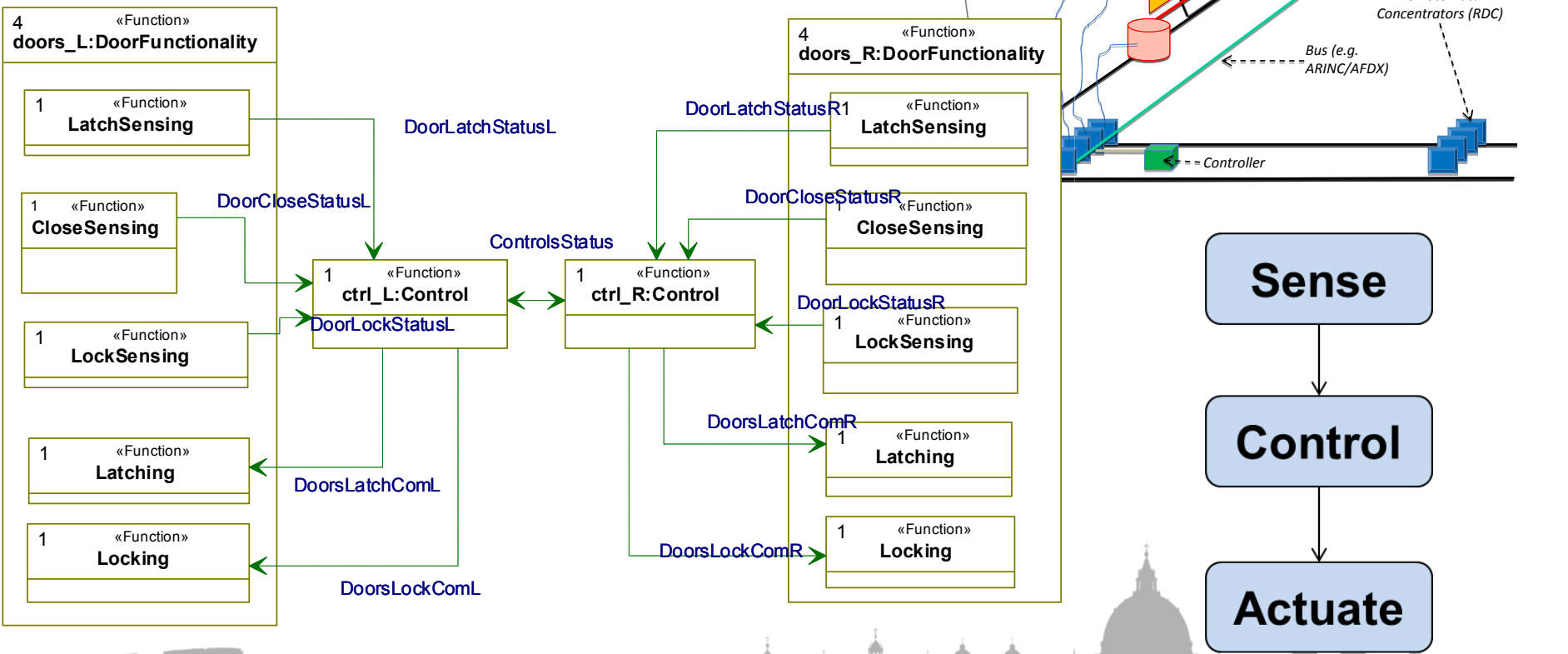
4. Optimized architecture back annotated to SysML model



* This work was partially sponsored by DARPA under contract #FA8650-10-C-7074.

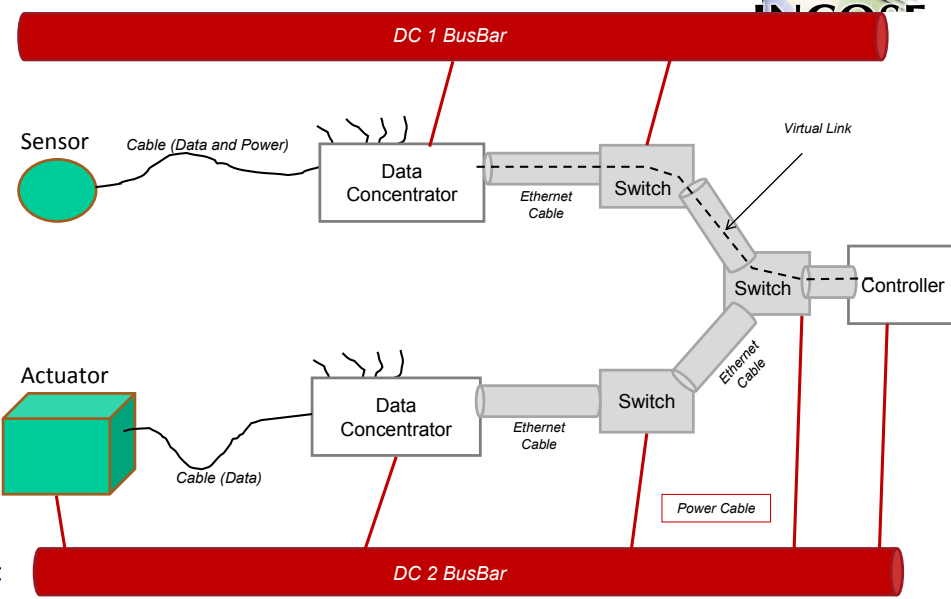
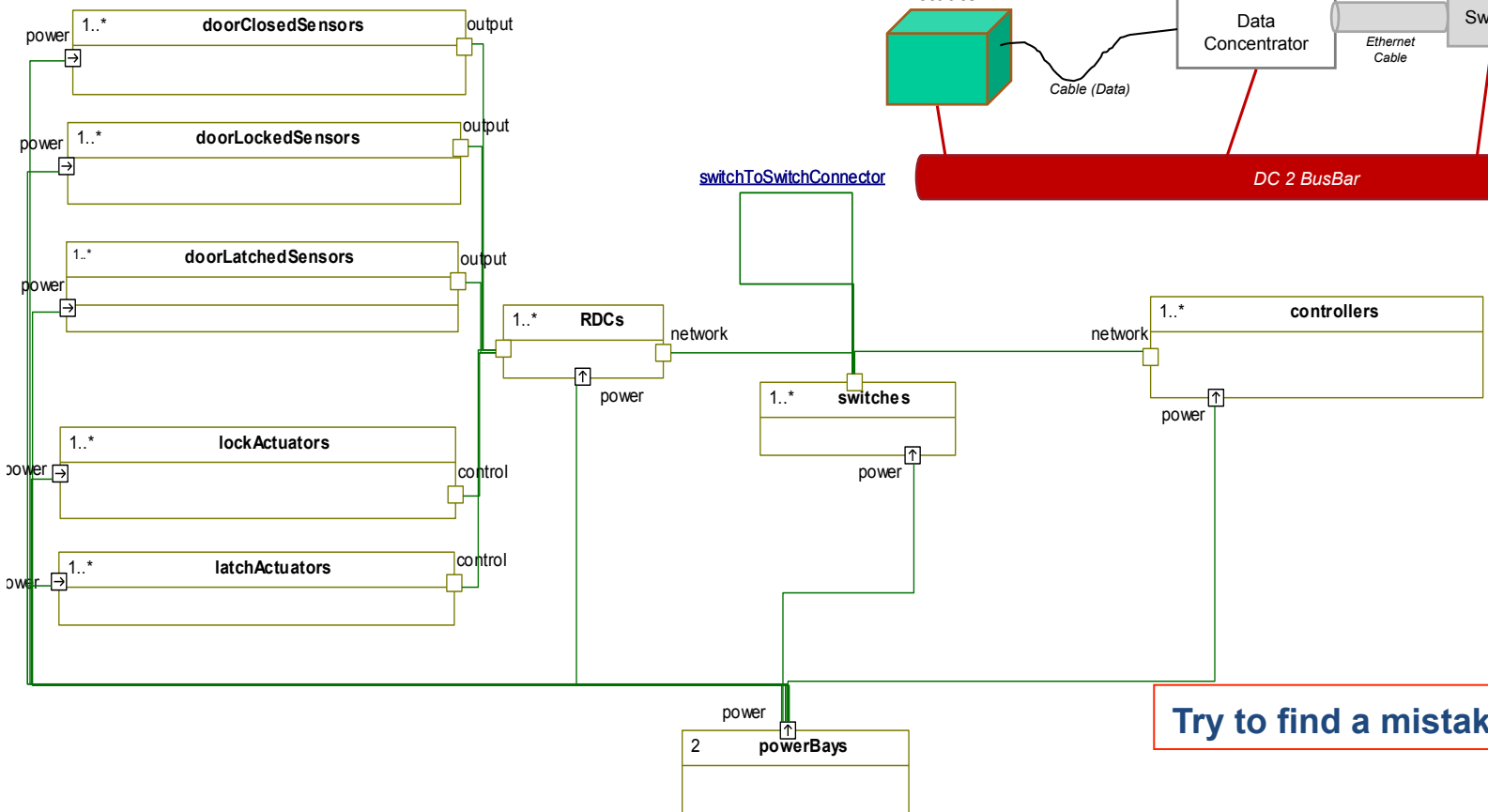
From user story to model

Functional Model



From user story to model

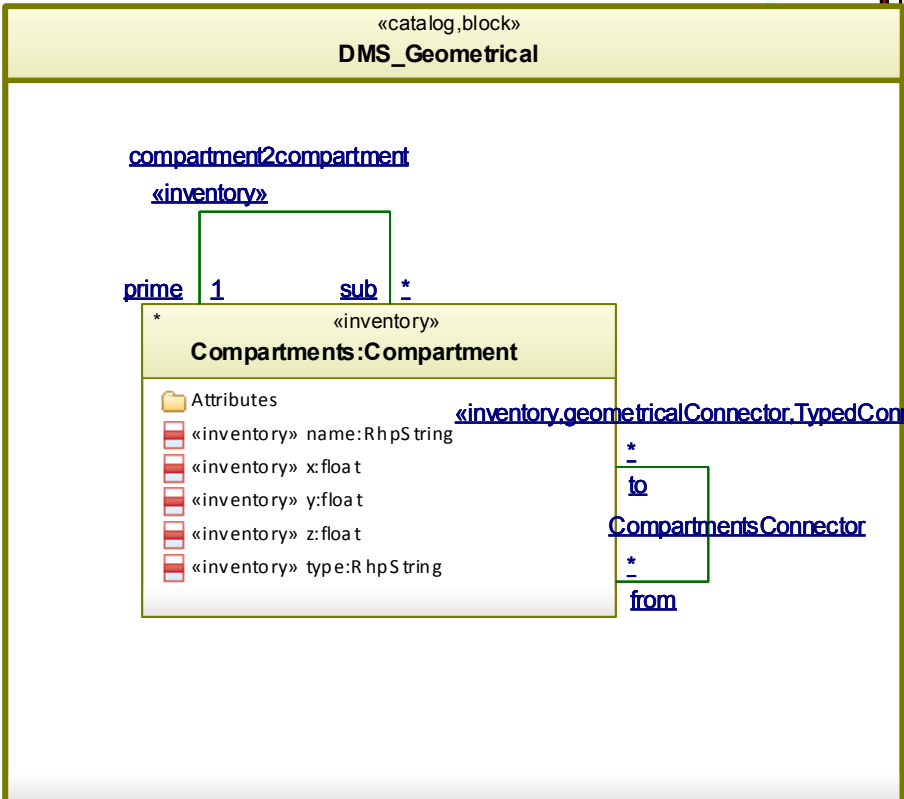
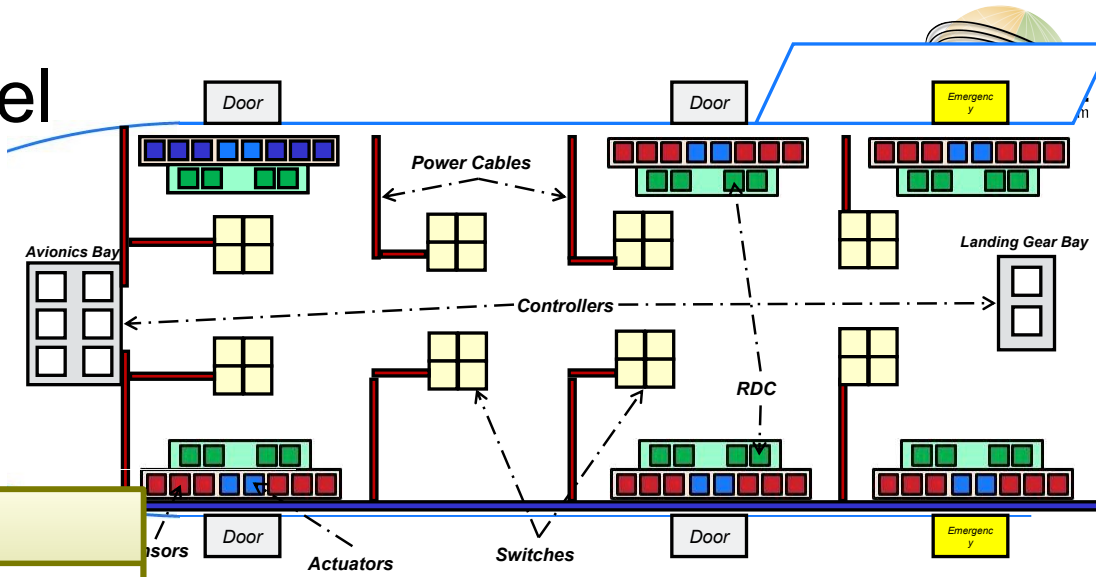
Architectural Template



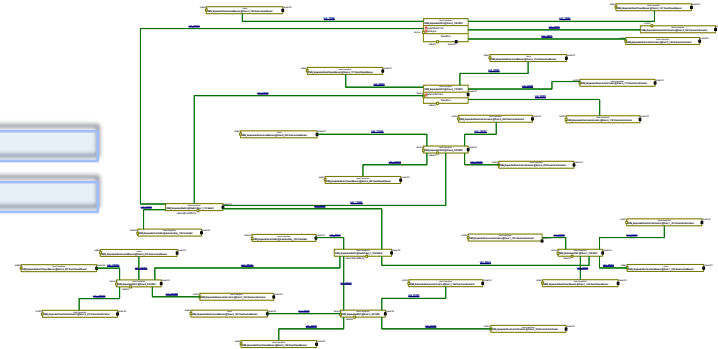
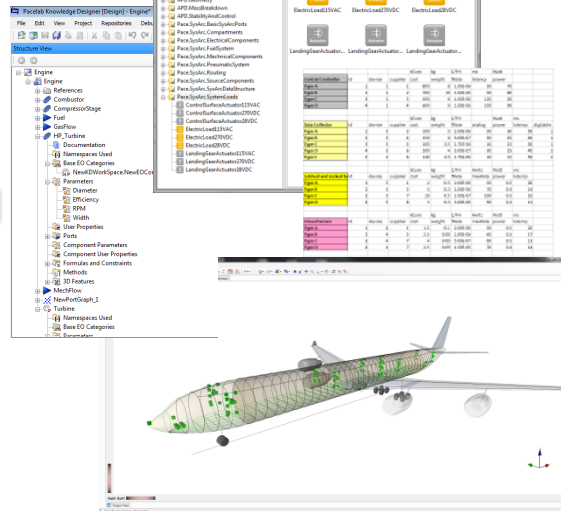
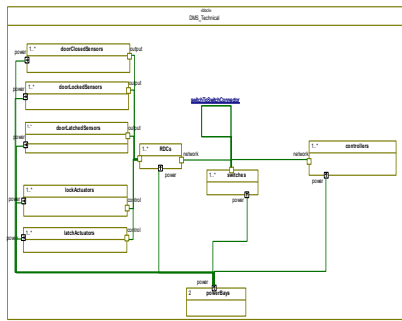
Try to find a mistake in the model

From user story to model

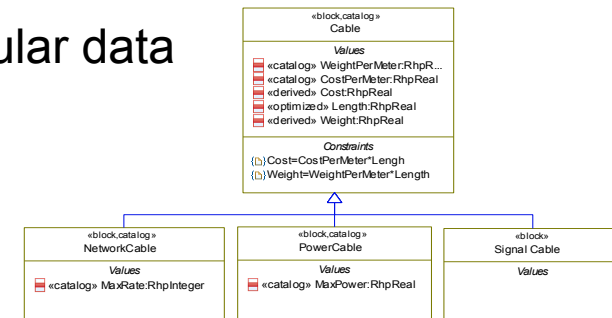
Geometrical Model



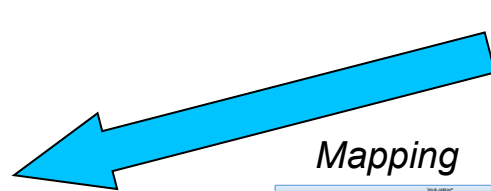
Concise Modeling



- Large systems architectures are difficult to model
 - Lots of elements and details
 - Time consuming
 - Error prone
- Concise Modeling – SysML models combined with tabular data
 - SysML depicts the system composition rules
 - Tables contain instantiations
- For an existing model the tabular data is taken from a component library
- Empty parameters to be filled by the optimization engine

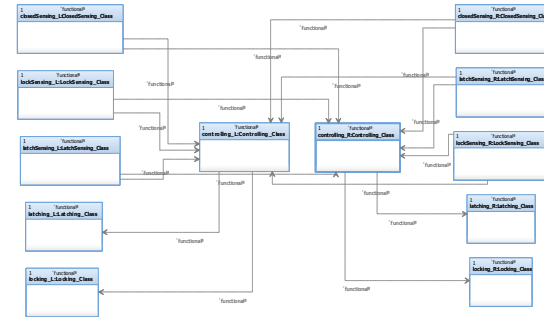
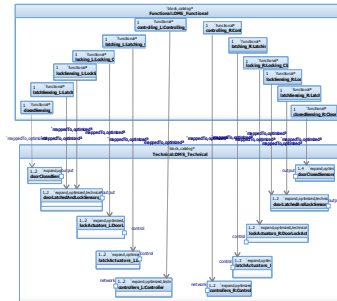


Concise modeling: views and relations

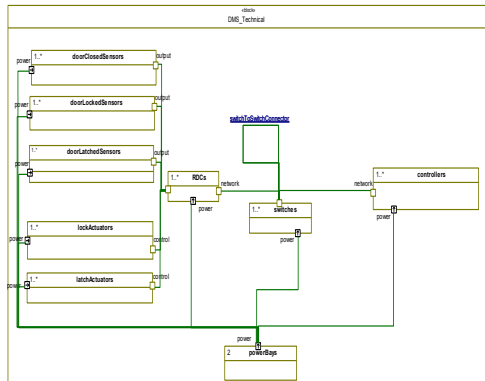


Functional

Mapping

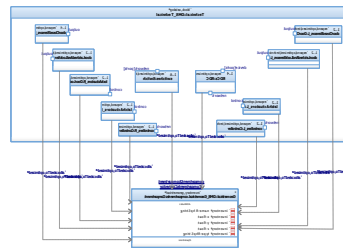


Technical

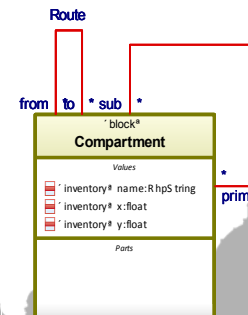


- Mapping is a means of defining what goes where
- Functions are mapped to a type of component or to a specific instance
- Components are mapped to a type of compartment or to a specific one

Mapping

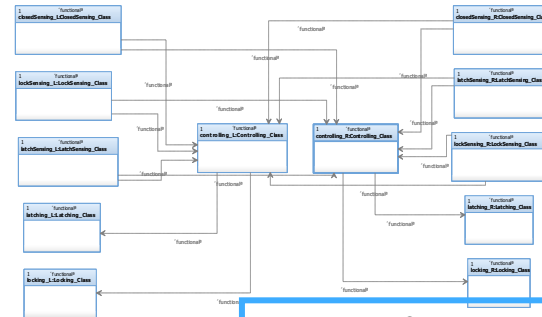


Geometrical

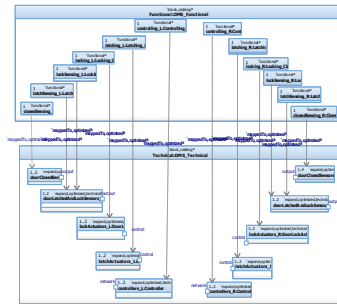


Concise modeling: views and relations

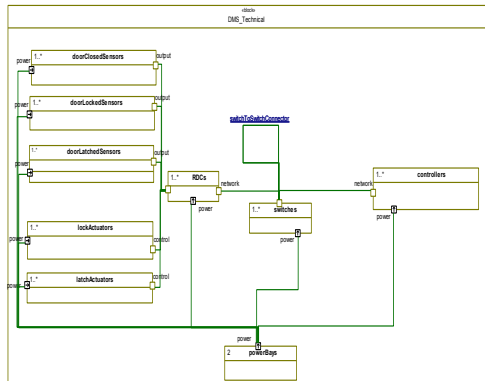
Functional



Mapping

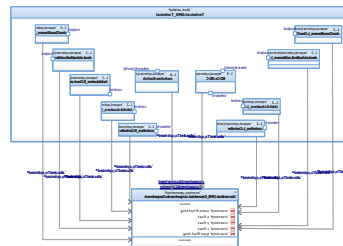


Technical

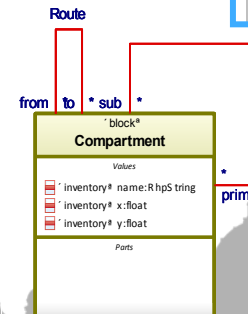


Automatic Generation

Mapping



Geometrical



Input & output structures

int	int	int
*id	sub	prime

Relations

int	int	string	int	float	float	float	float	int	float
*id	*typeid	typeName	ports	cost	rate	latency	power	supplier	weight
1	0								
2	0								
3	0								
4	0								
5	0								
6	0								

Inventory

int	int	int	int	float	float	float
*id	*typeid	area	device	x	y	z
1	37					
2	37					
3	37					
4	37					
5	37					
6	37					

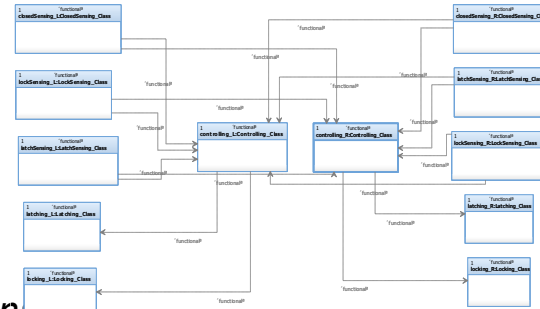
Indices

Placeid	Deviceid	linkType	cabinet	linkid	end1	end2	Cost	Weight	Length

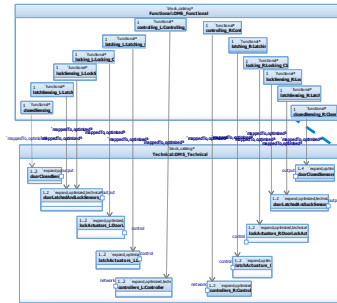
Output Tables

Concise modeling: views and relations

Functional



Mapping



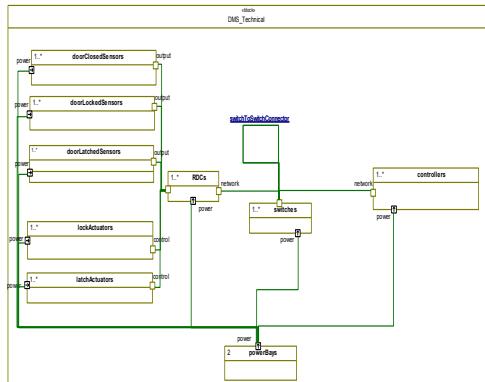
Relations

int	int
id	base
1	105
2	106
3	107
4	108
5	109
6	110
7	111
8	112
9	113
10	114

Geometry

int	float	float	float
id	x	y	z
1	2.2	0.5	-1
2	2.7	0.5	-1
3	2.2	0.3	-1
4	2.7	0.3	-1
5	2.2	0.1	-1
6	2.7	0.1	-1
7	2.2	-0.1	-1
8	2.7	-0.1	-1
9	2.2	-0.3	-1
10	2.7	-0.3	-1
11	2.2	-0.5	-1
12	2.7	-0.5	-1

Technical

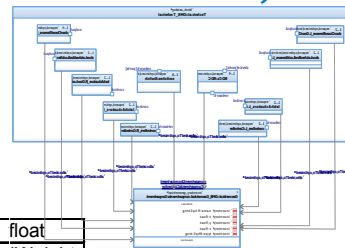


Component Library (PDM)

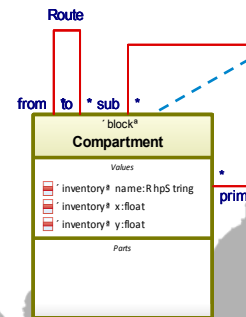
Catalog

int	float	float	float	int	int	float	int	float
id	fRate	latency	power	analog	cableType	totalCost	supplier	totalWeight
1	2E-06	50	30	50	1	100	3	5
2	5E-07	40	25	30	1	150	4	4
3	2E-06	50	15	16	1	100	5	2.5
4	5E-07	40	25	30	2	200	6	4
5	2E-06	50	15	16	2	130	6	2.5

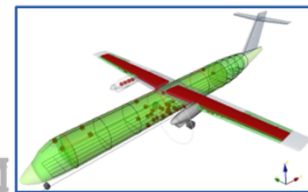
Mapping



Geometrical



Data

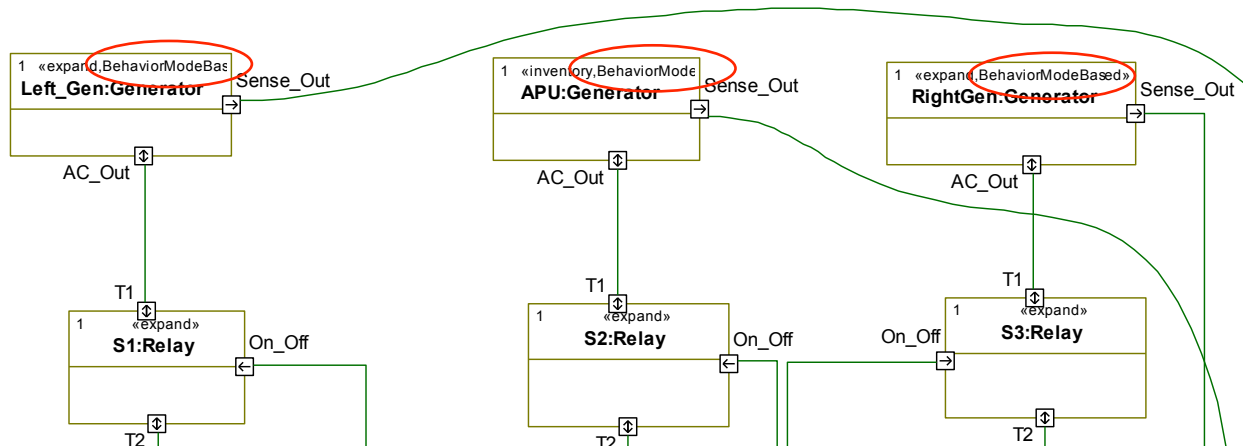
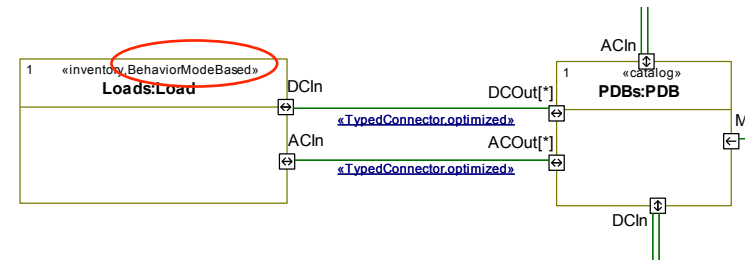


- 
- | Choice | |
|-------------------------|--------------------------|
| mandatory | ☐ |
| maxChildSelectionCardin | 1 |
| minChildSelectionCardin | 1 |



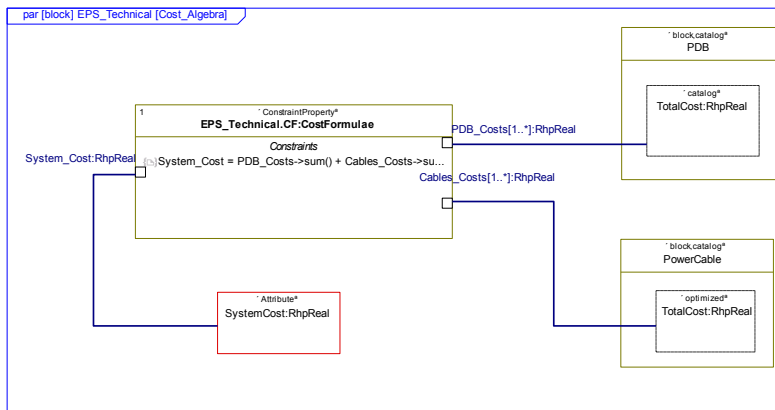
Scenario Modeling

- Systems have many operating modes and scenarios
 - Design must satisfy all
 - Modeling tools are needed to specify modes and scenarios
- Variability package extension
 - SysML based
 - Behavior modes groups
 - Modeling operating and failure modes

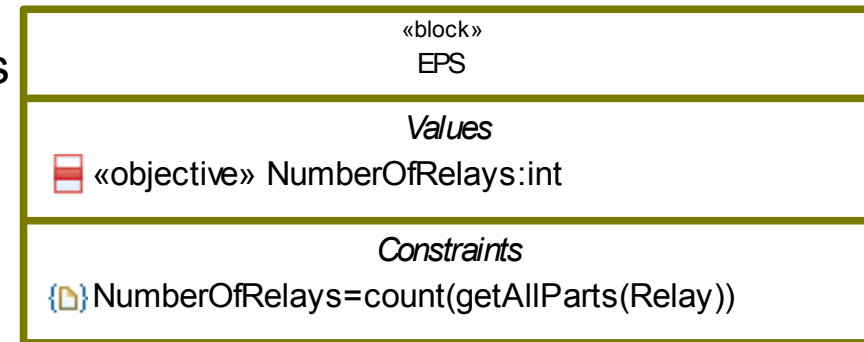


Objectives and constraints modeling - Algebras

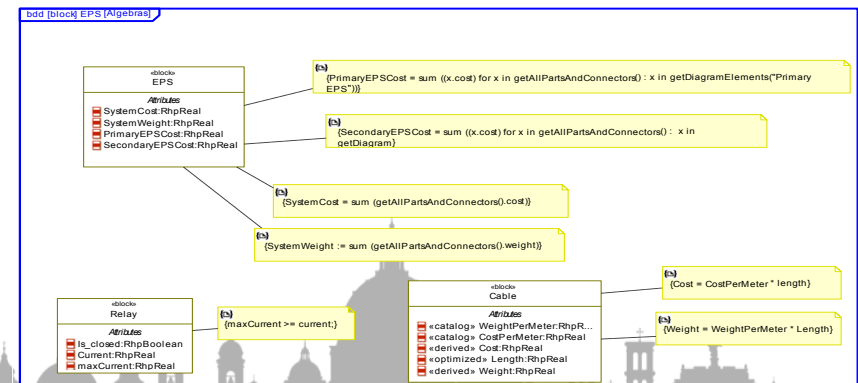
- Use SysML parametric diagram or textual notation
- Some metrics will be only referenced due to their complexity
- Use the object model (including concise) to define sets
- Model interrogation functions – additional means to define sets in absence of the actual architecture
- Stereotypes with tags to select objectives and define their constraints



Parametric Diagrams

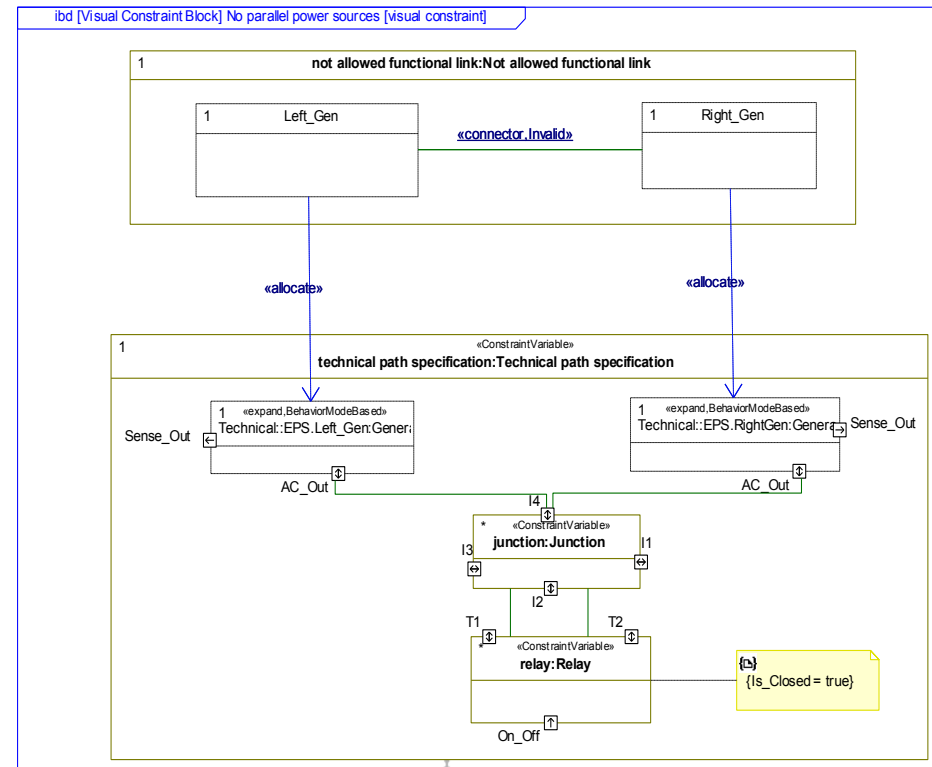


Stereotyped Comments



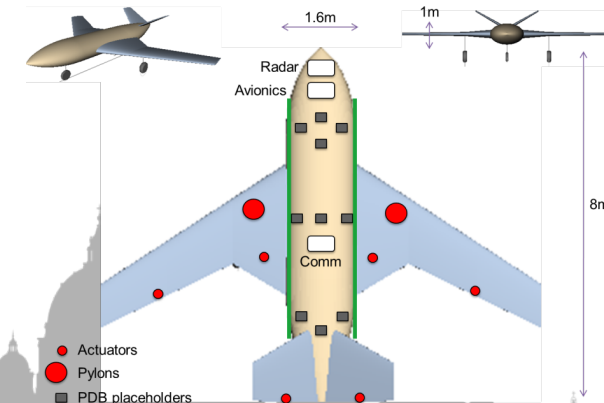
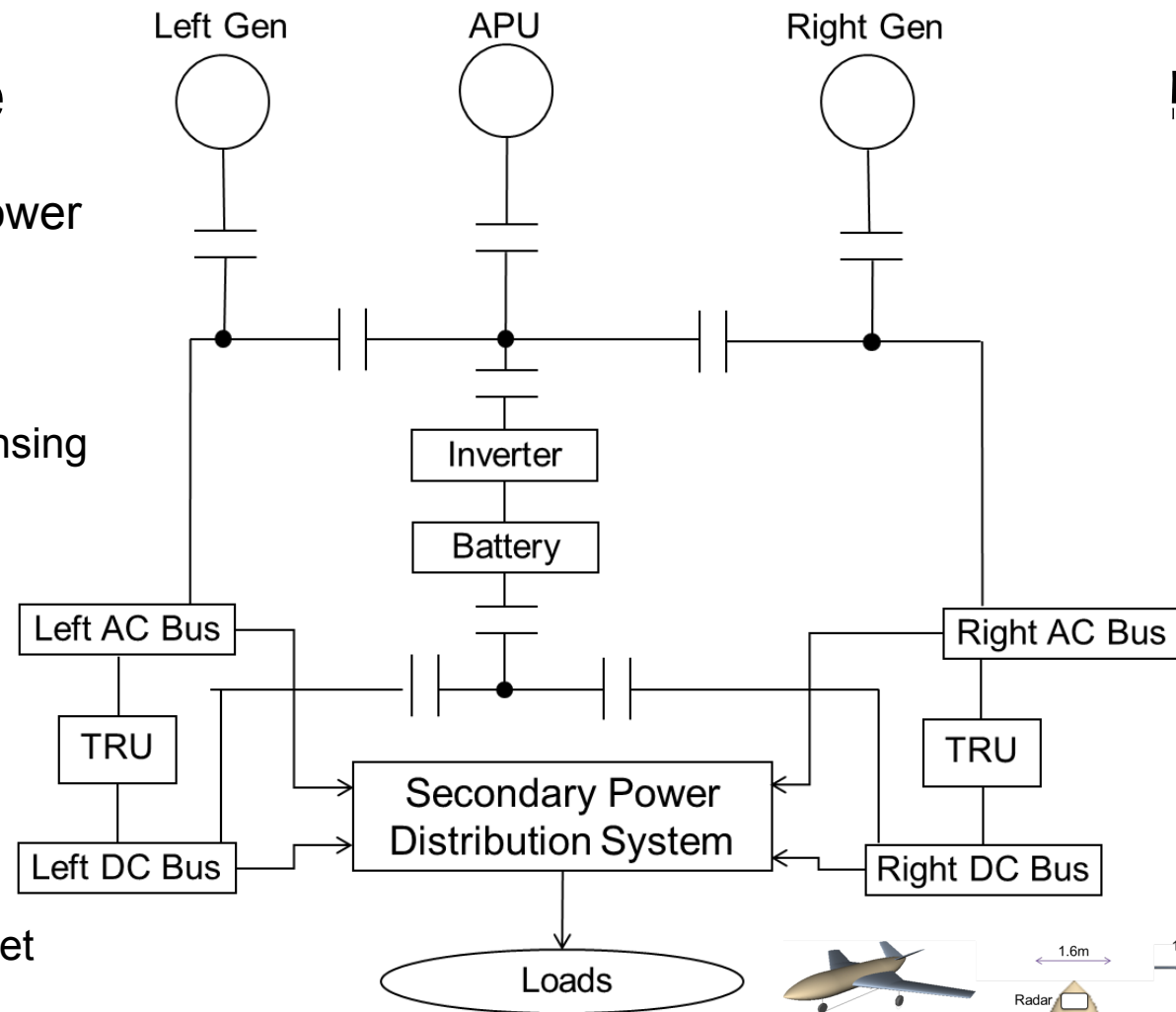
Constrains modeling - structure

- Constraints are given on the functional (requirements) level
 - Mapping needed to technical level
- New concept – constraints diagram
 - Model a functional link
 - Map to a structural template
 - Add link modifier
 - Should/should not exist
 - Related operational scenario
 - Probability information
 - Reliability/Timing/etc constraints on link



DSE Use case

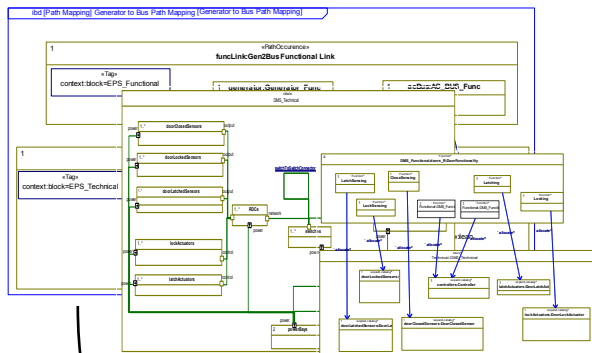
- EPS – Electrical Power System for UAV
 - Three generators
 - Single controller managing the sensing and switching
 - Loads on the secondary power system
- Objective
 - Optimize for cost and weight
 - Ensure system constraints are met



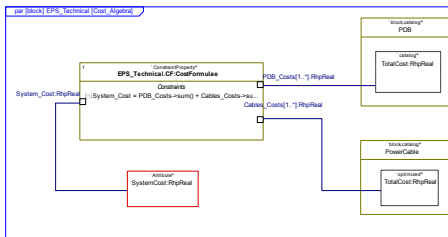
* Courtesy of United Technologies Corporation

Optimization Auto-Generation

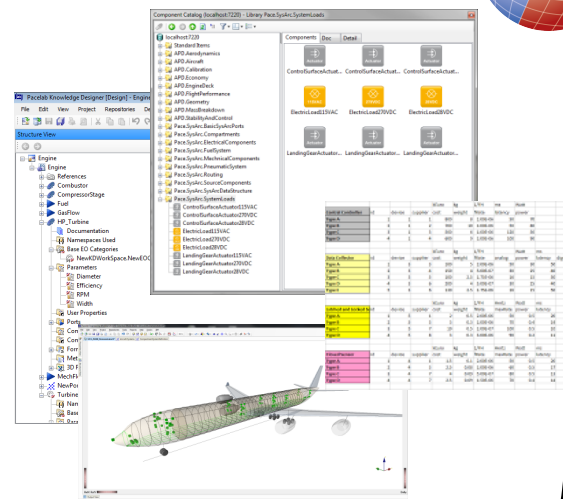
Requirements & Constraints



Metrics



Component library



Automatic Generation

Optimization Problem Formulation (CPLEX)

```

109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
200
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
238
239
240
241
242
243
244
245
246
247
248
249
250
251
252
253
254
255
256
257
258
259
260
261
262
263
264
265
266
267
268
269
270
271
272
273
274
275
276
277
278
279
280
281
282
283
284
285
286
287
288
289
290
291
292
293
294
295
296
297
298
299
300
301
302
303
304
305
306
307
308
309
310
311
312
313
314
315
316
317
318
319
320
321
322
323
324
325
326
327
328
329
330
331
332
333
334
335
336
337
338
339
340
341
342
343
344
345
346
347
348
349
350
351
352
353
354
355
356
357
358
359
360
361
362
363
364
365
366
367
368
369
370
371
372
373
374
375
376
377
378
379
380
381
382
383
384
385
386
387
388
389
390
391
392
393
394
395
396
397
398
399
400
401
402
403
404
405
406
407
408
409
410
411
412
413
414
415
416
417
418
419
420
421
422
423
424
425
426
427
428
429
430
431
432
433
434
435
436
437
438
439
440
441
442
443
444
445
446
447
448
449
450
451
452
453
454
455
456
457
458
459
460
461
462
463
464
465
466
467
468
469
470
471
472
473
474
475
476
477
478
479
480
481
482
483
484
485
486
487
488
489
490
491
492
493
494
495
496
497
498
499
500
501
502
503
504
505
506
507
508
509
510
511
512
513
514
515
516
517
518
519
520
521
522
523
524
525
526
527
528
529
530
531
532
533
534
535
536
537
538
539
540
541
542
543
544
545
546
547
548
549
550
551
552
553
554
555
556
557
558
559
560
561
562
563
564
565
566
567
568
569
570
571
572
573
574
575
576
577
578
579
580
581
582
583
584
585
586
587
588
589
590
591
592
593
594
595
596
597
598
599
600
601
602
603
604
605
606
607
608
609
610
611
612
613
614
615
616
617
618
619
620
621
622
623
624
625
626
627
628
629
630
631
632
633
634
635
636
637
638
639
640
641
642
643
644
645
646
647
648
649
650
651
652
653
654
655
656
657
658
659
660
661
662
663
664
665
666
667
668
669
670
671
672
673
674
675
676
677
678
679
680
681
682
683
684
685
686
687
688
689
690
691
692
693
694
695
696
697
698
699
700
701
702
703
704
705
706
707
708
709
710
711
712
713
714
715
716
717
718
719
720
721
722
723
724
725
726
727
728
729
730
731
732
733
734
735
736
737
738
739
740
741
742
743
744
745
746
747
748
749
750
751
752
753
754
755
756
757
758
759
760
761
762
763
764
765
766
767
768
769
770
771
772
773
774
775
776
777
778
779
780
781
782
783
784
785
786
787
788
789
790
791
792
793
794
795
796
797
798
799
800
801
802
803
804
805
806
807
808
809
810
811
812
813
814
815
816
817
818
819
820
821
822
823
824
825
826
827
828
829
830
831
832
833
834
835
836
837
838
839
840
841
842
843
844
845
846
847
848
849
850
851
852
853
854
855
856
857
858
859
860
861
862
863
864
865
866
867
868
869
870
871
872
873
874
875
876
877
878
879
880
881
882
883
884
885
886
887
888
889
890
891
892
893
894
895
896
897
898
899
900
901
902
903
904
905
906
907
908
909
910
911
912
913
914
915
916
917
918
919
920
921
922
923
924
925
926
927
928
929
930
931
932
933
934
935
936
937
938
939
940
941
942
943
944
945
946
947
948
949
950
951
952
953
954
955
956
957
958
959
960
961
962
963
964
965
966
967
968
969
970
971
972
973
974
975
976
977
978
979
980
981
982
983
984
985
986
987
988
989
990
991
992
993
994
995
996
997
998
999
1000

```

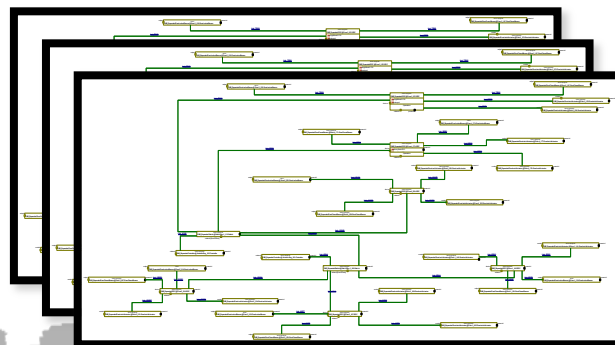


Calculation of Efficient Frontier

The chart displays the following data points for each model:

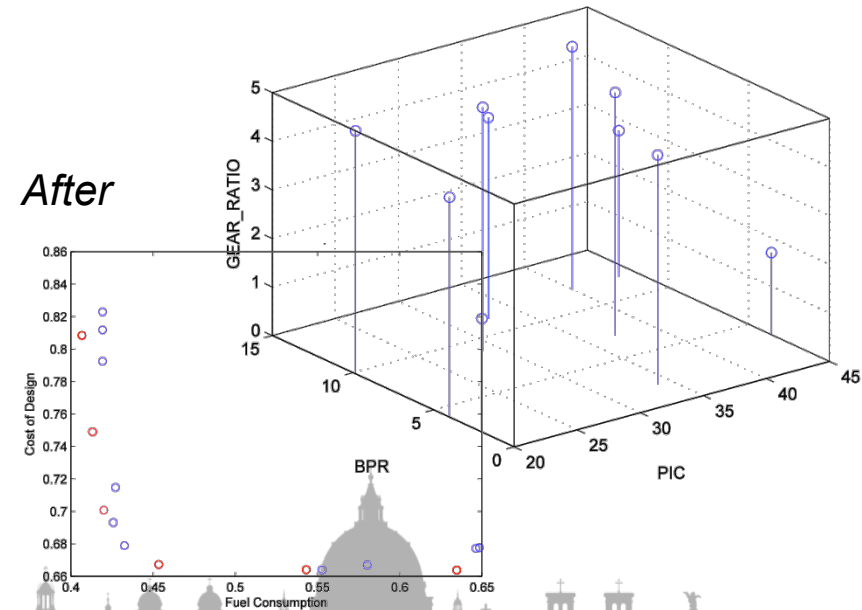
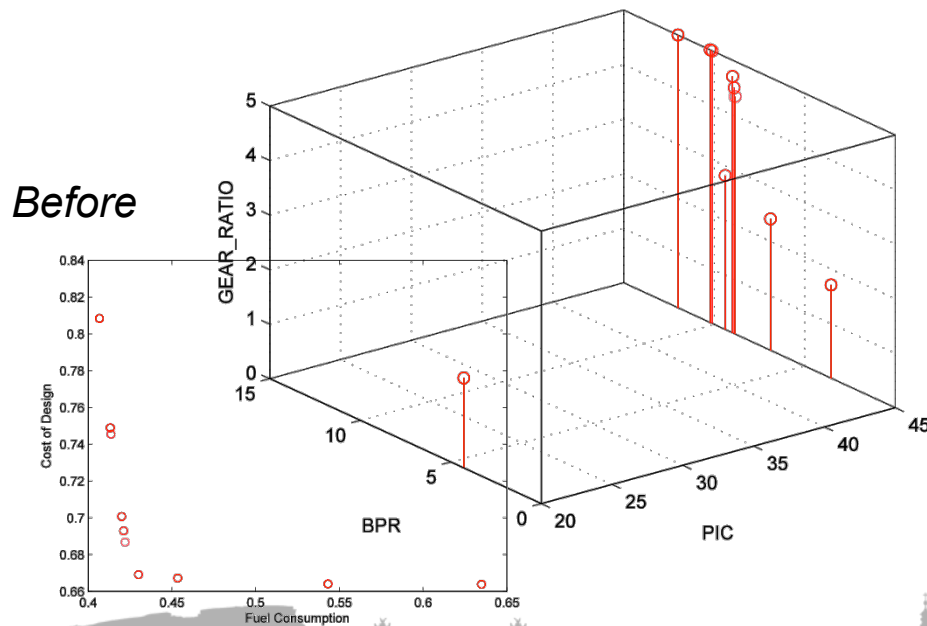
Model	Cost (Red)	Weight (Green)	Reliability (Blue)	Complexity (Yellow)
GPT-4o	350.00	370.00	366.80	104.84
Gemini 1.5 Pro	320.00	360.00	375.00	110.00
Claude 3.5 Sonnet	350.00	370.00	375.00	110.00
LLaMA 3.3 Instruct	350.00	370.00	375.00	110.00

Selection of desired options



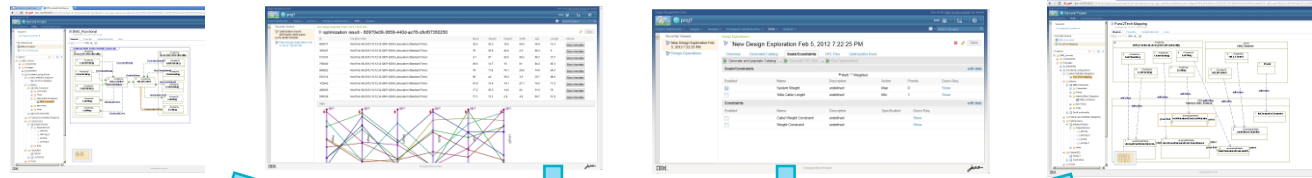
Diversity Maximization Algorithms

- Points on efficient frontier often represent very similar architectures
 - No real choice is given
 - No boost in innovation
- Existing genetic algorithms do not guarantee maximum diversity and are computationally heavy.
- Our algorithms guarantee maximal designs diversity under allowed deviation (distance) from the efficient frontier

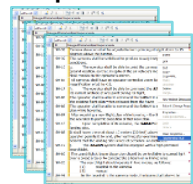


Process and Tools overview

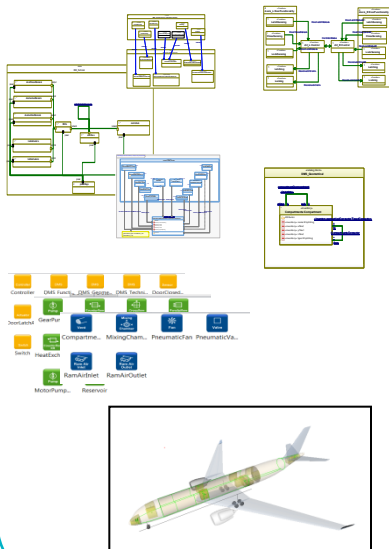
Architect's cockpit



Requirements

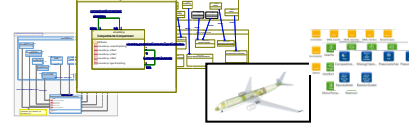


Conceptual design With Concise Modeling & Component Libs



Perform Design Exploration

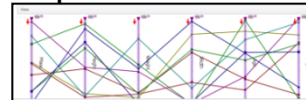
Publish and Tune



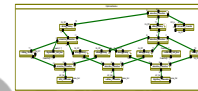
Auto Translate to Optimization Model & Solve



Explore Alternatives



Visualize Alternatives

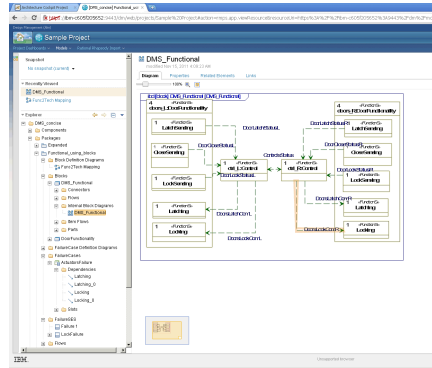


Analysis & Simulation

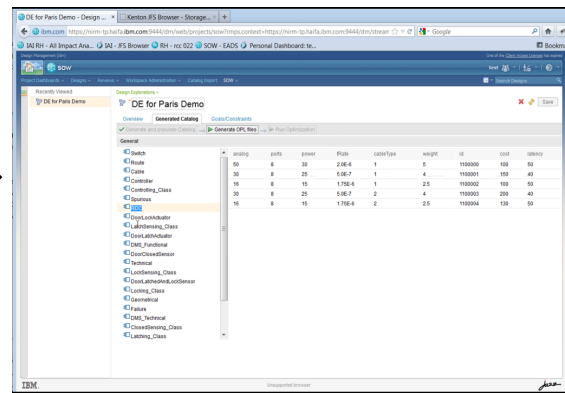


Architect Cockpit

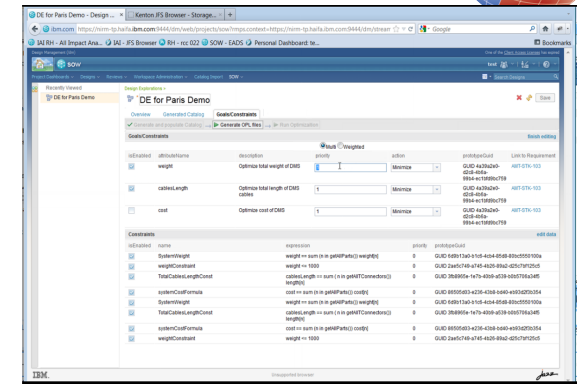
Modeling management



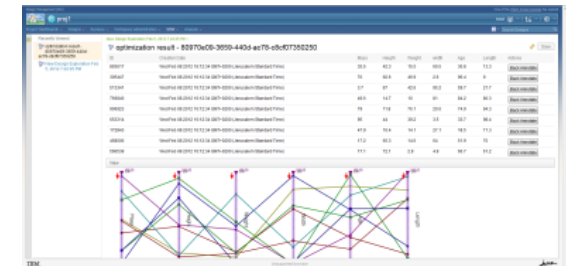
Data management



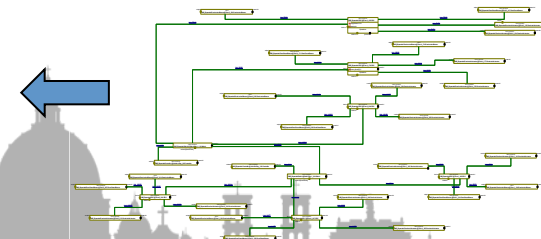
Objectives management



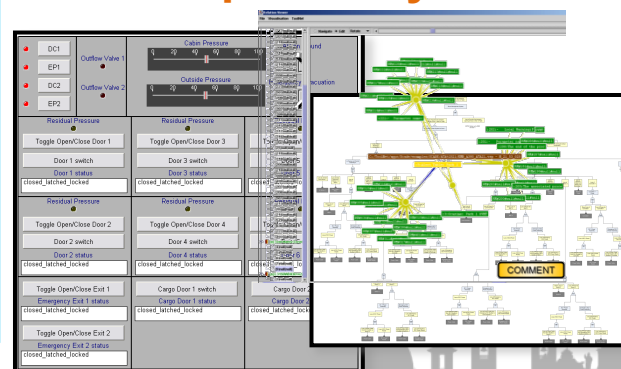
Results management



Back-Annotation



Multiple Analyses



- Single environment
 - Main tool of the Systems Engineer
 - Controlling the design and analysis process
- Based on Design Manager and JTS
- Interaction with modeling environments
 - Review and comment mechanisms
 - Cross organizational collaboration
 - Models import / export control
 - Back-end model transformations
- Integration with analysis tools
 - Simulations, computations, domain specific views
 - White-box, black-box
 - Analysis results feedback into models
- Visual analytics

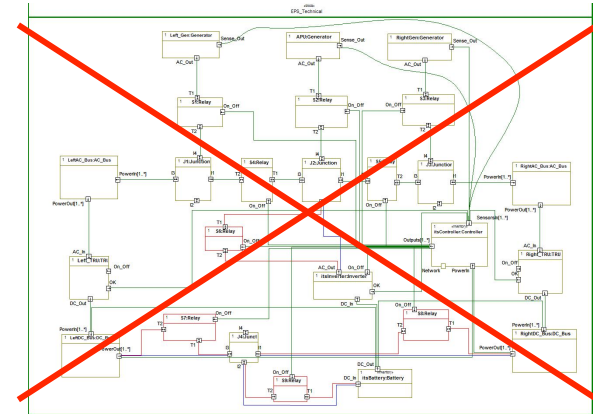
Thank you

Questions?



Design Space Exploration - METHODS

- Define SysML extensions for concise systems modeling
 - Composition rules rather than complete structures
 - Add structural constraints
 - Component libraries as third party input via structured interchange format
 - Define contracts for the system and its components – behavioral constraints
 - Define variables algebras (e.g. weight, cost, complexity etc)
- Add variability points - choices
- Add optimization enabling data to the model
 - Define objectives
 - Add constraints



GCU.C1.Assumption:= [E "Gen.failed"] implies [C Gen.status=failed] holds forever
 GCU.C1.Guarantee:=whenever [E "GCU.recv_gen_failure"] occurs [E "GCU.send_gen_failure"] within (+GCU_send_delay)]
 GCU.C2.Guarantee:=whenever [E "GCU.recv_gen_failure"] occurs [E "GCU.send_open_gen_relay"] within (+GCU_send_delay)]
 GCU.C3.Guarantee:=whenever [E "GCU.recv_command com" and not (com=="send_open_gen_relay" and C GCU.gen_status_failed)] occurs [E "GCU.send_command com"] within (+GCU_send_delay)]

int	int	string	int	float	float	float	float	int	float	int	int
*id	typeid	typeName	ports	cost	fRate	latency	power	supplier	weight	vls	cableType
1	0										
2	0										
3	0										
4	0										
5	0										
6	0										

int	int	int	int	int	int	int	int	int	int	int	int
id	sub	prime	id	sub	prime	id	sub	prime	id	sub	prime
1											
2											
3											
4											
5											
6											

+

+

