ICSSEA 2016

Tutorial 1 – MBSE
Gradual modeling approach to support development of complex systems

Raphaël Faudou
raphael.faudou@samares-engineering.com

Introduction

Why so much noise about MBSE?

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Model-Based Systems Engineering (MBSE) is the formalized application of modelling to support system requirements, design, analysis, verification and validation, beginning in the conceptual design phase and continuing throughout development and later life cycle phases.

INCOSE SYSTEMS ENGINEERING VISION 2020, INCOSE-TP-2004-004-02, Version 2.03, September 2007

From "promising approach"…

FROM

Model-based systems engineering has grown in popularity as a way to deal with the limitations of document-based approaches, but is still in an early stage of maturity similar to the early days of CAD/CAE.

… to "established practice"

TO

Formal systems modeling is standard practice for specifying, analyzing, designing, and verifying systems, and is fully integrated with other engineering models. System models are adapted to the application domain, and include a broad spectrum of models for representing all aspects of systems. The use of internet-driven knowledge representation and immersive technologies enable highly efficient and shared human understanding of systems in a virtual environment that span the full life cycle from concept through development, manufacturing, operations, and support.

Systems Engineers have to adapt

INCOSE SYSTEMS ENGINEERING VISION 2025, 2014

Lessons learnt on MBSE in industry

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- **MBSE is hard to define**
  - Identify the right starting modelling approach
  - Choosing right modeling language/notation
  - Choosing / customizing / integrating right tooling

Where to start?

- **MBSE is hard to apply**
  - 3 big changes: new modeling notation, method and tool…

… often suggested / imposed with unquantified benefits …

… generally teached in same way for all people and projects…

… with some distance with their vocabulary and practices

Many systems engineers do not feel comfortable with MBSE application : they mainly complain about complexity of modeling language and of tool

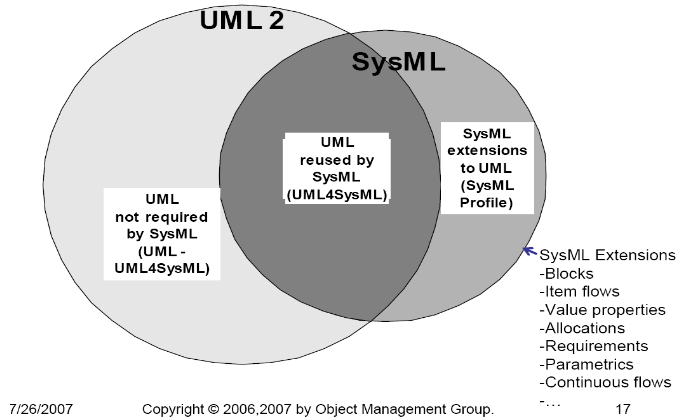
Why is MBSE perceived as complex?

- **SE deals with a lot of view points to address**
  - Requires many different concepts to characterize them
  - ➔ large modeling language or a large set of small languages

- **SE modeling languages are not domain specific**
  - Mapping to do between modeling concepts and domain glossary

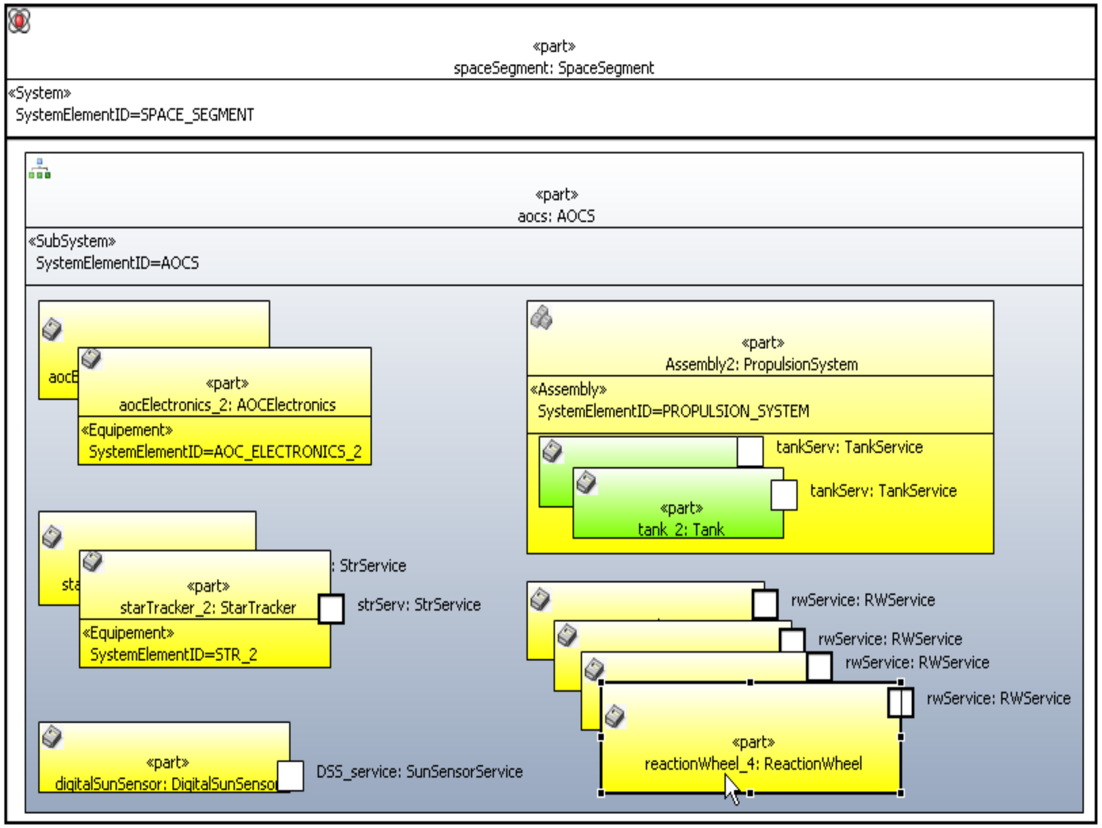
- **Most SysML tool vendors failed to hide UML for years**
  - SysML tools were first designed as UML tools with additional menus

"Visio and Excel are enough for me"



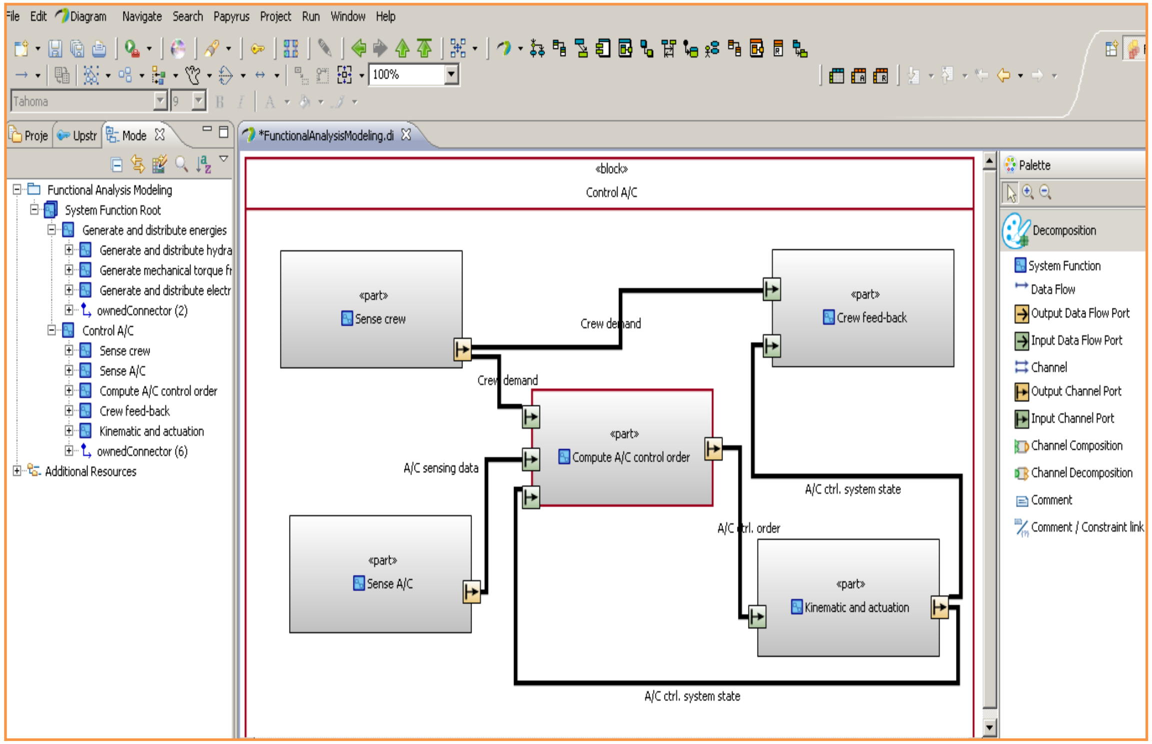
What can be done? (1)

- **Adapt (specialize) language to your domain**
  - Example (space industry) – SysML IBD specialized to align on ECSS vocabulary (system, subsystem, assembly, device…)



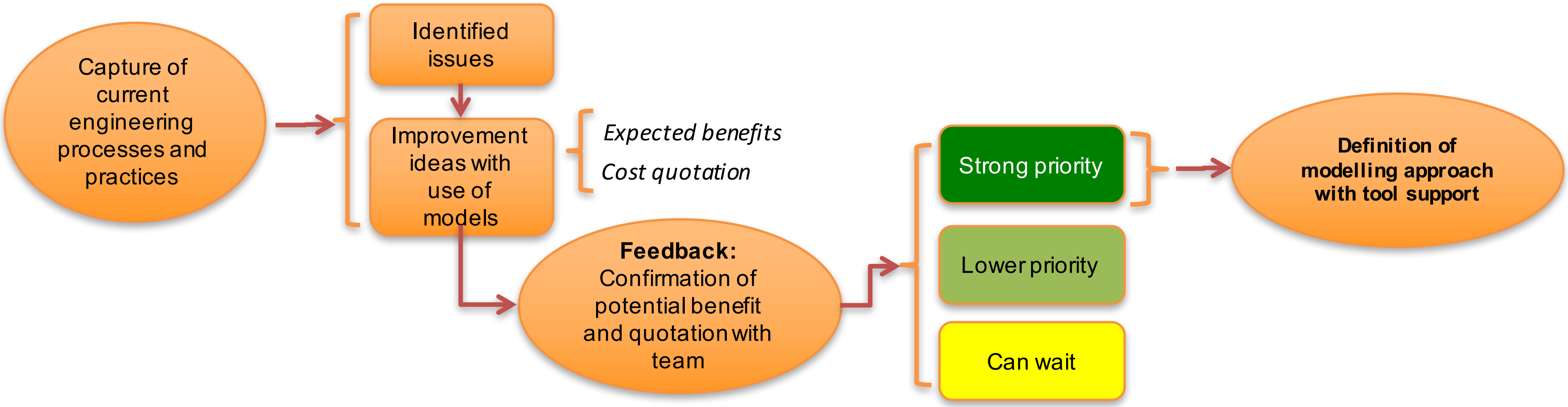
What can be done? (2)

- **Adapt (specialize and restrict) tool to daily activities**
  - Example (Aeronautics industry) : Functional architecture editor based on SysML but providing a very limited set of features (only the ones required by system function designer)



How to transition to MBSE?

Simple pragmatic MBSE (1)



1. **Start from processes and practices (not from tool)**

2. **Focus on efforts reduction (improve adoption)**

3. **Limit scope (early demonstration of benefits)**

Simple pragmatic MBSE (2)

4. Keep it simple

1. Few concepts and views ➔ easy to learn

5. Engage modeling expert for model creation

1. Very limited disturbance for team
2. Fast ramp-up for model

6. Transfer modeling knowledge with coaching

1. Dedicated training ➔ ensures adoption, favors dissemination

7. Identify additional savings with advanced tooling

1. Prepare roadmap and wider adoption with more benefits

Tutorial organization

- **Part A – Simple pragmatic MBSE in practice**
  - Present standard engineering technical processes and possible support of activities by formal models
  - Use of a fictive but realistic case study for practical illustration
  - Introduction of concrete benefits captured in industry

- **Part B – Some keys toward advanced MBSE**
  - Understand MBSE potential and constraints
  - Incremental MBSE deployment and remaining challenges

Part A
Simple pragmatic MBSE in practice

Case study
A better solution for phytosanitary treatment in agriculture

Current farming solutions: tractors

- **Tractor can sometimes become stuck in the mud**
  - Not the right solution when it rains: can be catastrophic when target treatment period is short

- **Tractor wheels crush part of the harvest**

Current farming solutions: airplanes

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- **Airplanes lack of precision**
  - Extra cost of spray
  - Risk of treatment spread outside the target field
- **Airplane rent is an issue**
  - Too high cost for acquisition
  - Rent not always available on target period

Current farming solutions - Helicopters

- Helicopters have better precision than aiplanes
- But are still more expensive than tractors
- And are difficult to rent (lack of availability in target periods) like airplanes

What about Unmanned Aerial Vehicle ?

- **Treatment product can be spread very precisely**
  - Can limit treatment product to the plant and then limit needed volume and associated water
  - Can follow field cartography and increase agriculture performance

- **Can operate after the rain**

- **Probably less expensive than airplane and helicopter**

- **Less physical effort in case of auto pilot**

UAV solution for phytosanitary treatment

You are now a UAV vendor (1)

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- Can you define a product that fits farmer expectations about treatment?

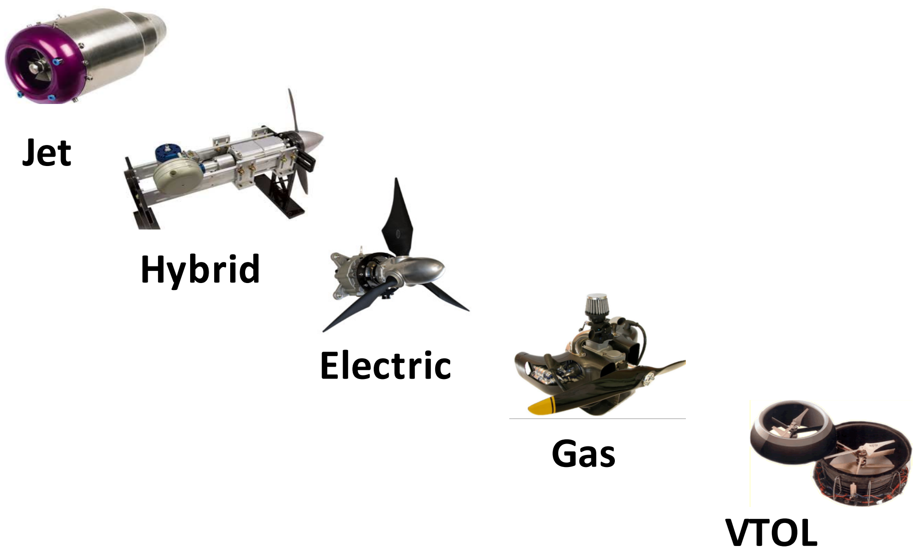
- Exercise 1: can you choose the right shape ?



- Can you provide rationale for your choice?

You are now a UAV vendor (2)

- Exercise 2: can you choose the right propulsion technology?



- Exercise 3: can you choose the right spray nozzle technology? The right pump?

First facet of Systems Engineering

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- **A complex system requires specialists…**
  - Aeronautics specialists
  - Propulsion specialists
  - Hydraulic specialists
  - Navigation specialists
  - Mechanical specialists
  - Energy specialists
  - …

- **… and systems engineers, able to understand the problem and discuss with specialists to define together one "optimal" system architecture that satisfies the problem**

Lessons learnt from industry

- **Do not focus on solution first…**
  - Else there is high risk that you miss the target

- **For the farmer, business focus is not in acquisition of a new system: it is to <u>treat the plant at lower cost than the previous year => MISSION FIRST !</u>**

Business or Mission Analysis

Process purpose (ISO 15288:2015)

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"The purpose of the Business or Mission Analysis process is to define the business or mission problem or opportunity, characterize the solution space and determine potential solution class(es) that could address a problem or take advantage of an opportunity"

- **Main steps**
  - Identify major stakeholders
  - Define the problem or opportunity space: market context and vision
  - Define operational context, other life cycle context, comprehensive set of solution classes
  - Define business requirements and validation criteria

Major stakeholders (business)

- **Marketing department**
  - Identify opportunities
  - Build the vision
- **Operation department**
  - Identify company experience and skills
- **Farmer representatives**
  - Confirm drawbacks on current solutions,
  - Provide feedback on their cost equation
- **Agriculture ministry and local representatives**
  - Political trends,
  - Envisioned public subsidies

Market context

- **Geographical context**
  - First target is France agriculture (at least for a few years)
  - Target agricultural area is around 25 Ha (250,000 m2)
- **Political context (France)**
  - Favors ecology and "Green" solutions
  - Encourage low water consumption
  - Encourage optimized use of treatment spray
- **Economic context**
  - Can probably get funding to invest on "Green solutions"

Vision

- **Innovative solution with very low consumption of spray**
  - Very precise treatment only focused on plant => flight plan
  - Can work with no sun to limit evaporation => at night? Radar?
- **Low water consumption**
  - Special spray nozzles with high precision technology
- **Very high amplitude of use**
  - Can be used after rain
  - Can be used with strong slopes=> terrain detection
- **Limited control efforts**
  - Automated pilot => flight plan
  - Autonomous on energy?
  - Autonomous on spray reload?

Operational context

- Field, with shape and dimensions, slopes (altitudes)
- Harvest to treat: height, width,…?
- Weather: Humidity, wind, temperature
- Obstacles between base and target field
- Potential presence of humans or animals in the field
- Base for monitoring, base for refill, base for energy

Operational scenario

- **Main scenario**
  - Requisite: a flight plan exists for field treatment
  - Step 1: activate UAV (performs check-in tests)
  - Step 2: Fill treatment spray
  - Step 3: load configuration including flight plant (reading tests)
  - Step 4: launch UAV for treatment mission
  - Step 5: monitor mission with regular position feedback

- **Alternate steps:**
  - 4.A. Refill spray and continue mission
  - 4.B. Refill energy or change battery and continue mission
  - 5.A Loss of communication

Business requirements + validation

- **BR1: solution shall be able to treat a field automatically**
  - Target performance: 25 Ha within 2 hours
- **BR2: solution shall be able to treat with no luminosity**
  - Target performance: at night, with no moon or clouds
- **BR3: solution shall be able to consume very little water**
  - Target performance is less than 15 l / ha
- **BR4: solution operating cost shall be attractive**
  - Target performance is less than 110% of tractor' operating cost
- **BR5: solution shall be safe and only treat target field**
  - Target performance is 2 m maximum outside of the field

Key parameters and constraints

- **Product**
  - Flight speed during treatment (m/s)
  - Energy autonomy (hours)
  - Payload (Kgs) or effective spray capacity (l)
- **Mission**
  - Treatment duration (hours)
  - Distance from remote operator < 1 Km
- **Mission context**
  - Field surface (ha)
  - Harvest inter row distance (m)
  - Weather conditions
  - Wind, temperature, humidity
  - Water concentration (l/ha)

Key parameters bindings

- Treatment duration = treatment distance / speed
- Treatment distance = harvest surface / inter row space
- Treated surface before loss of spray = payload / water concentration
- Global mass = UAV mass (without payload) + payload

Feasibility, sizing and segment marketing

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- **Inject values on key properties and explore impacts**
  - Some derived values might be out of range: means risks on feasibility
  - Variation thresholds: can reveal solution classes or market segments

- **Example of assumptions, analysis and decisions**
  - For 10 l/Ha concentration and 200 l spray capacity **20 Ha** can be treated before re filling. But can we offer 200 Kg payload?
  - Lithium technology batteries can support 20 mn flight time for limited mass. With two nozzles (two rows), it requires a speed of **180 km/h** to treat 20 ha within 20 mn => **not feasible with intended precision**.

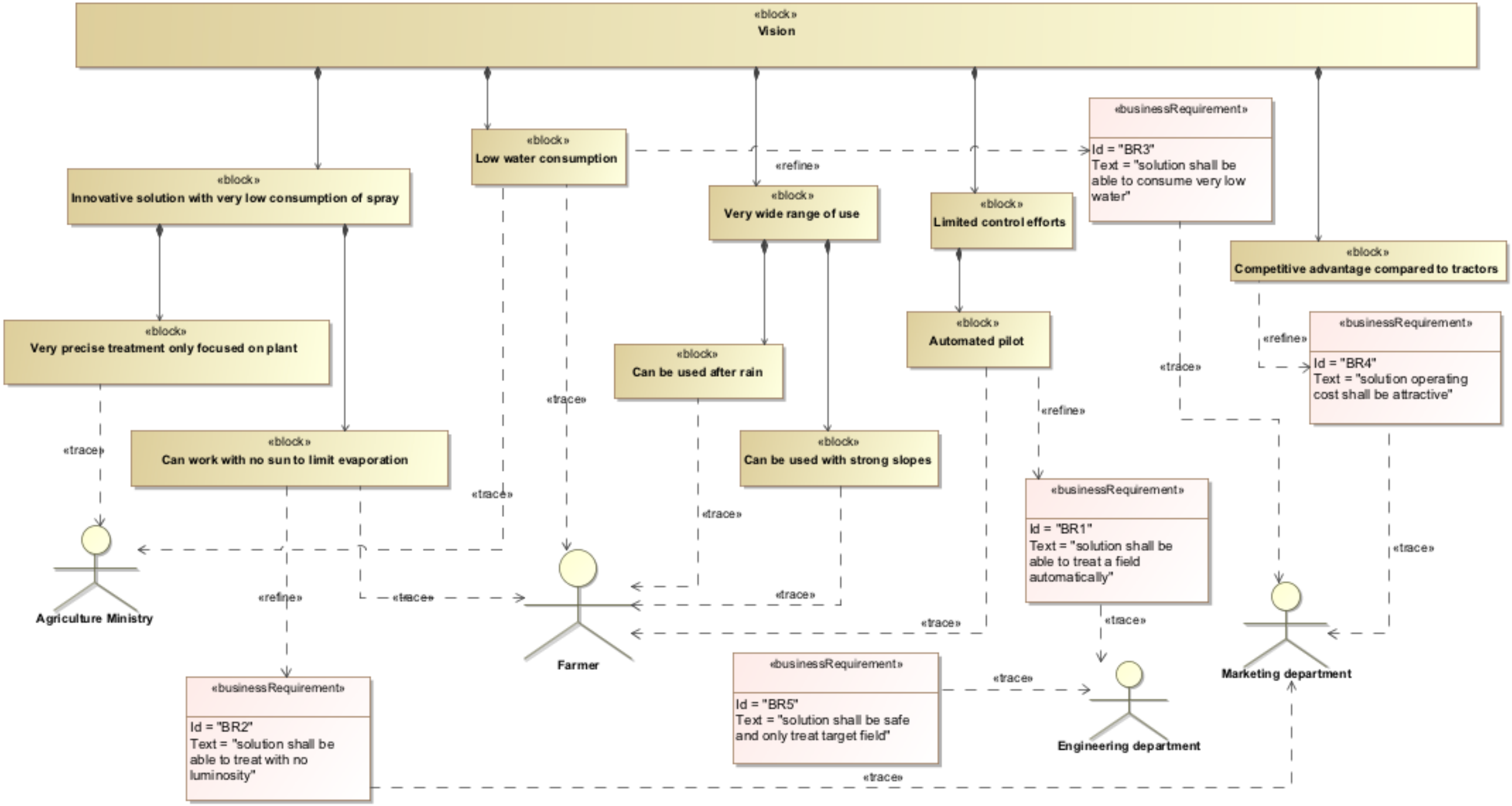
{http://rivaldrones.com/make-your-drone-go-farther-with-intelligent-energys-range-extender-technology/}

Decision 1: Investigate use of battery extender technology (hydrogen fuel cell) to reach 2h autonomy.
Decision 2: Investigate use of extender device for nozzles in order to treat more than 2 rows at same time (take care of additional mass…)

Benefits of models for *Business and Mission Analysis*

Structured view with links helps managing traceability

Vision decomposed, refined and traced to major stakeholders and business requirements (SysML block definition diagram)



Centralized, structured, synthetic glossary

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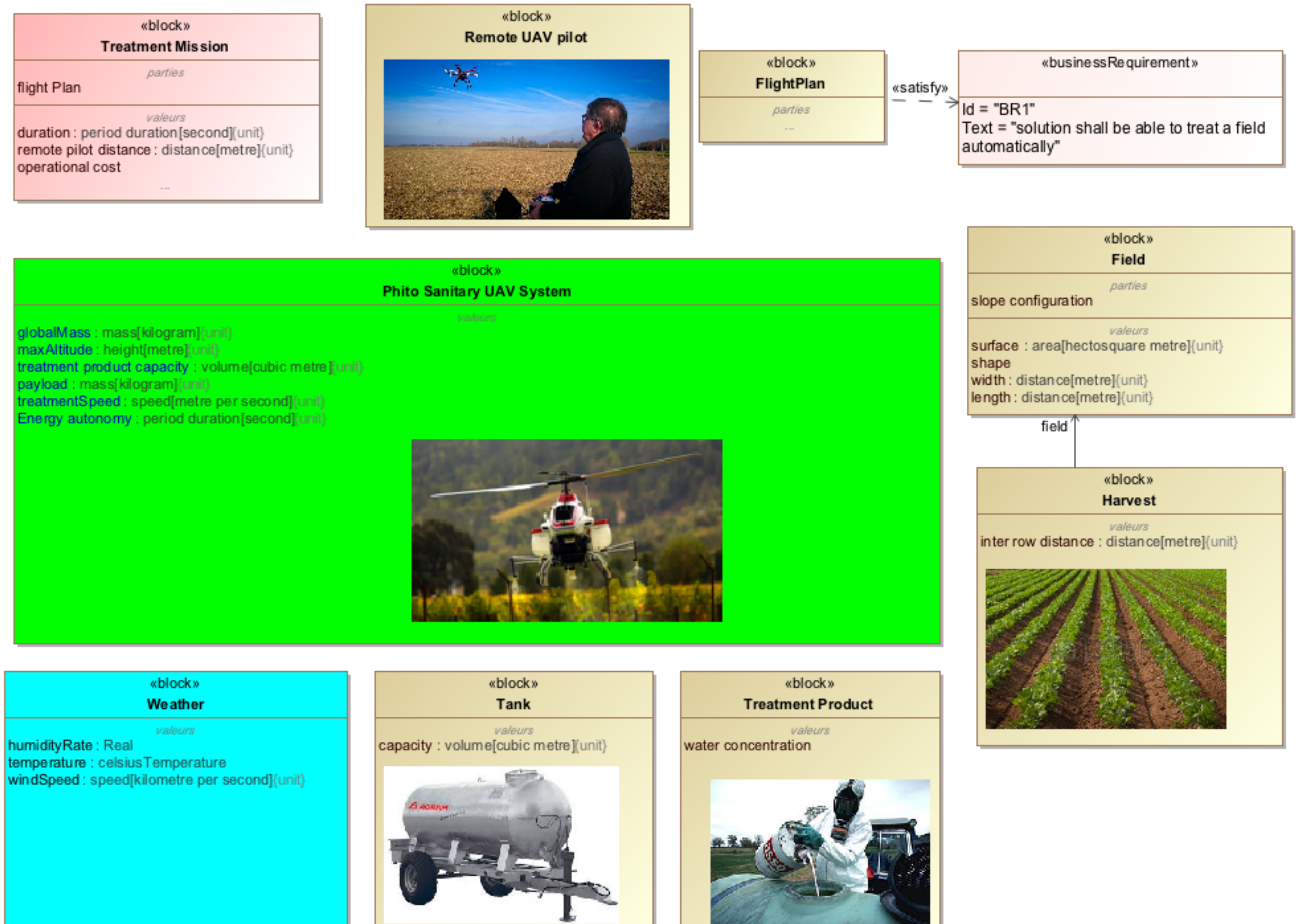
Operational context: set of structured definitions with key properties (SysML block definition diagram)



Visual support for configuration definition

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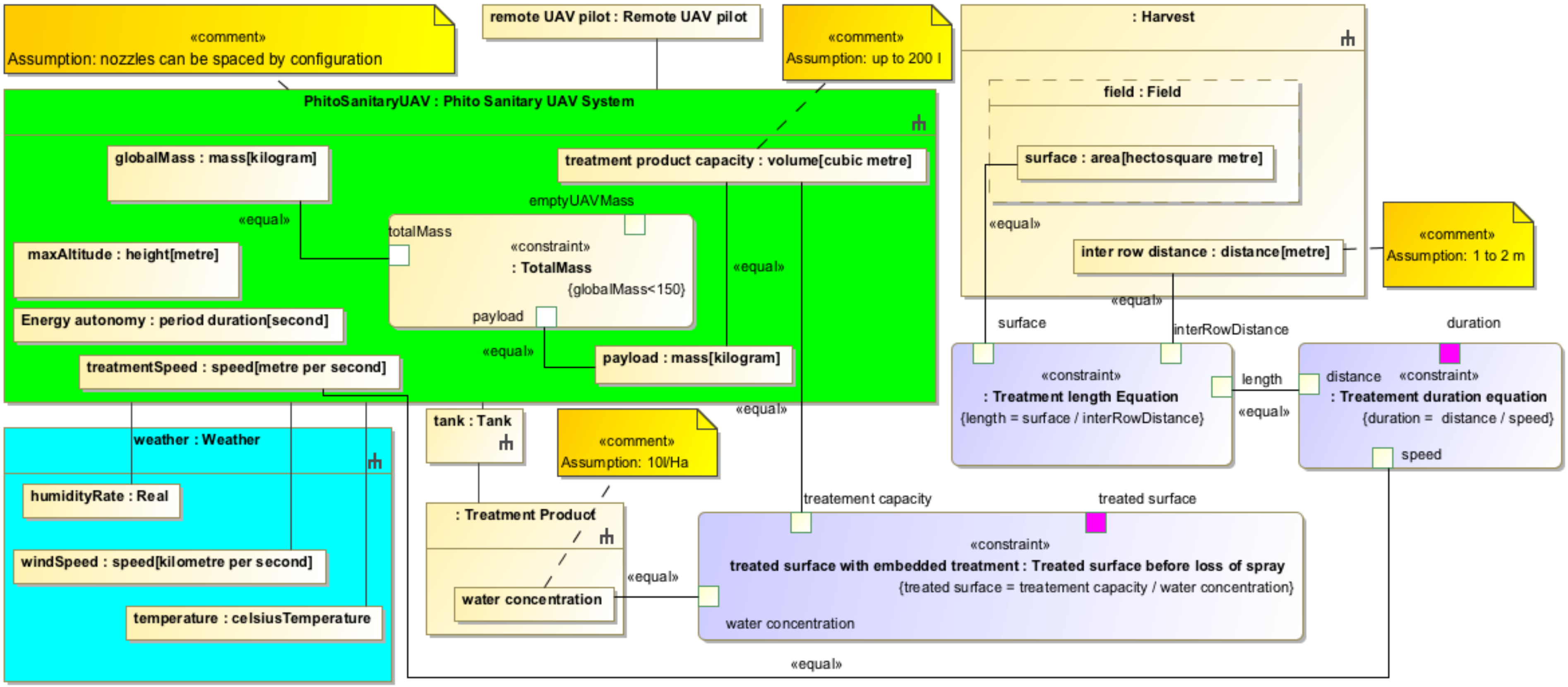
Equations/constraints bind operational context properties and assumptions drive analysis and decisions (SysML internal block diagram)



Different views complete in one model: several focus but global consistency

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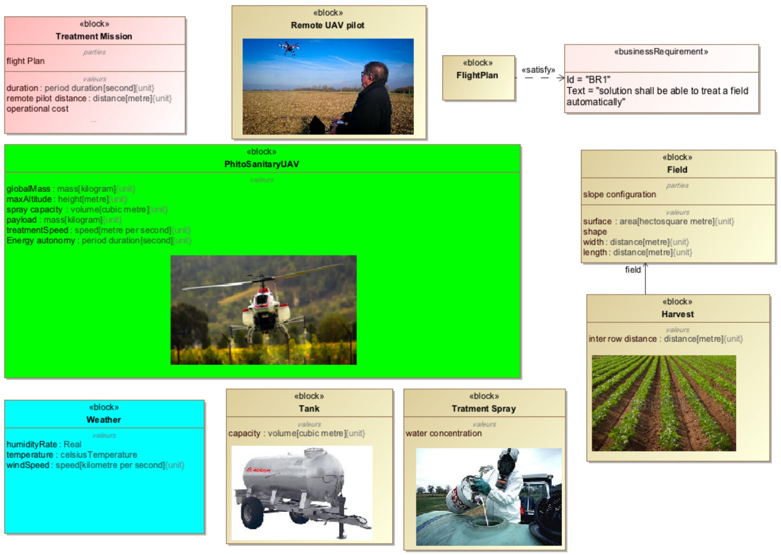
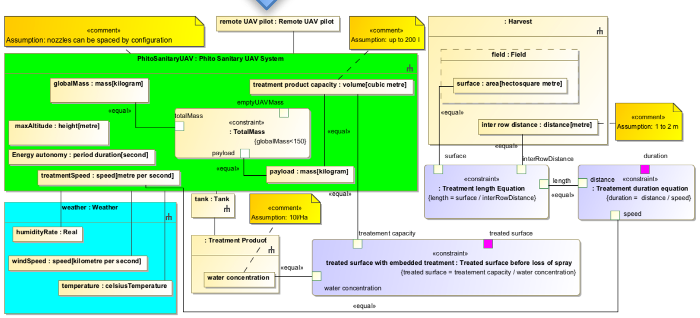
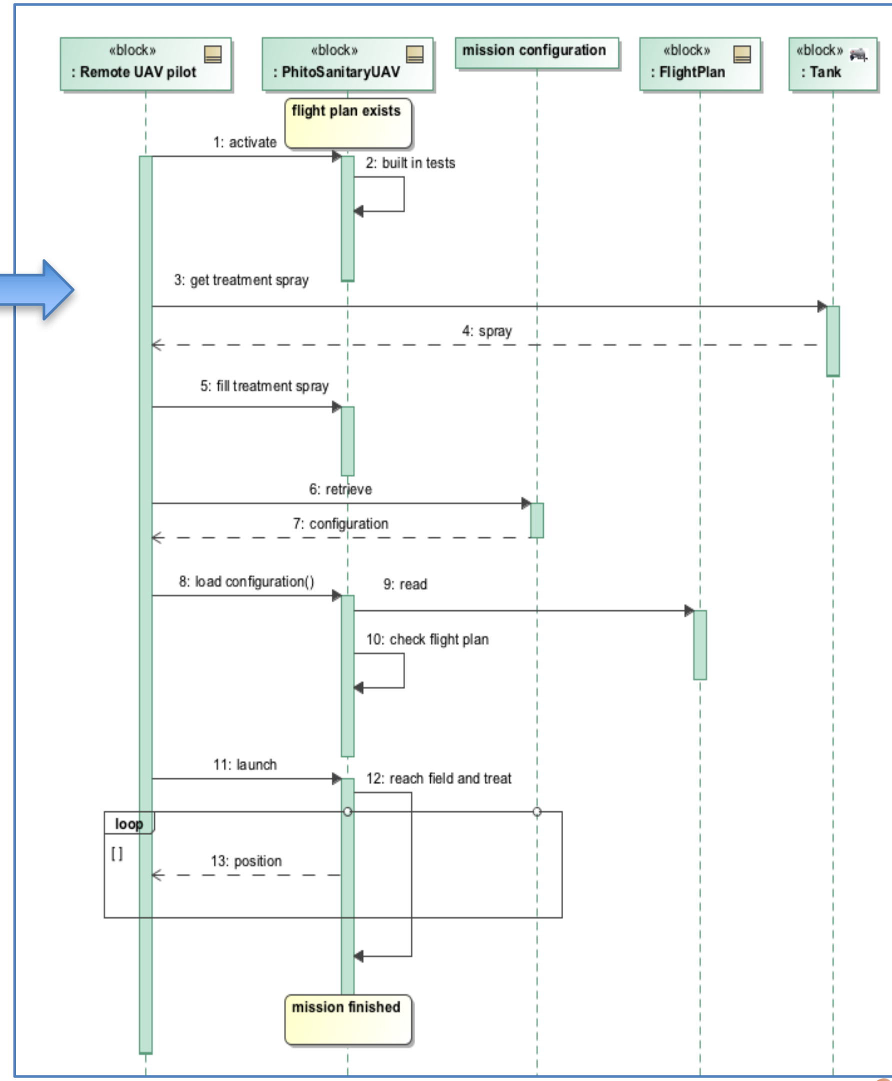
Operational scenario between context elements (SysML sequence diagram)



Propagation of new added properties

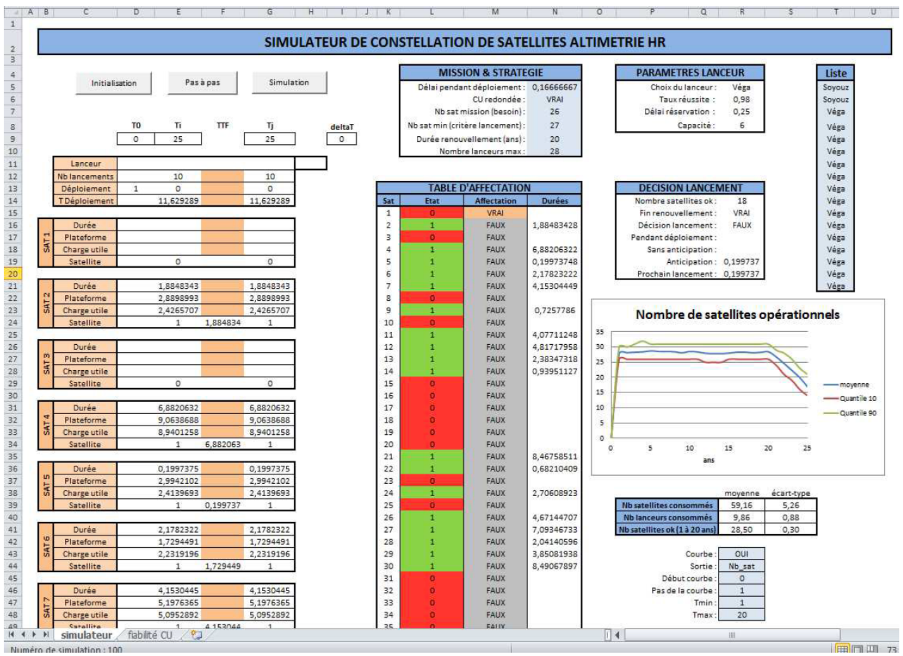




Formal model as a marketing asset

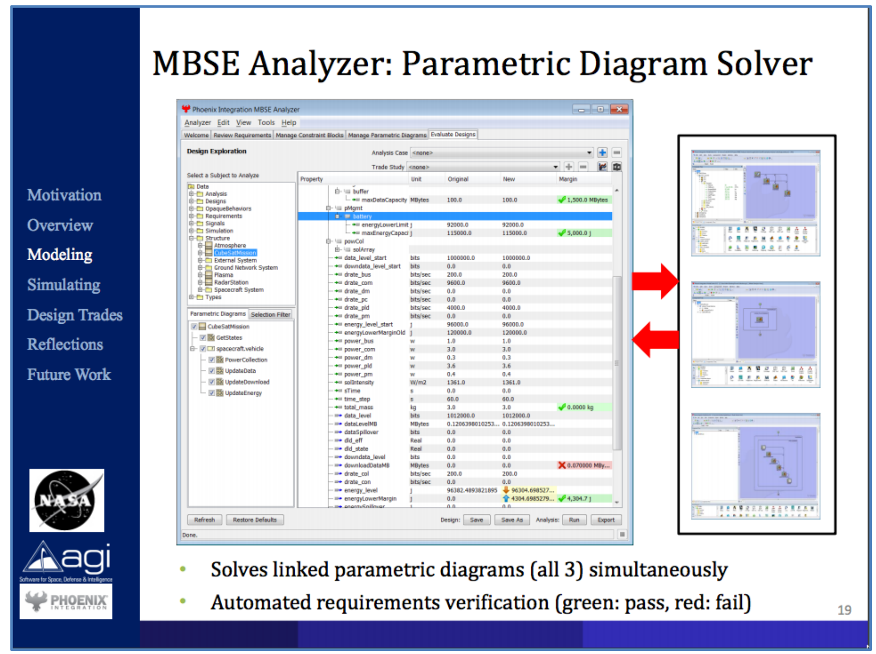
- Model can be used as the reference for marketing data and can be completed to drive decisions (cost, risk…)

Excel-based solution to simulate satellite constellation



{Sébastien Bosse, CNES}

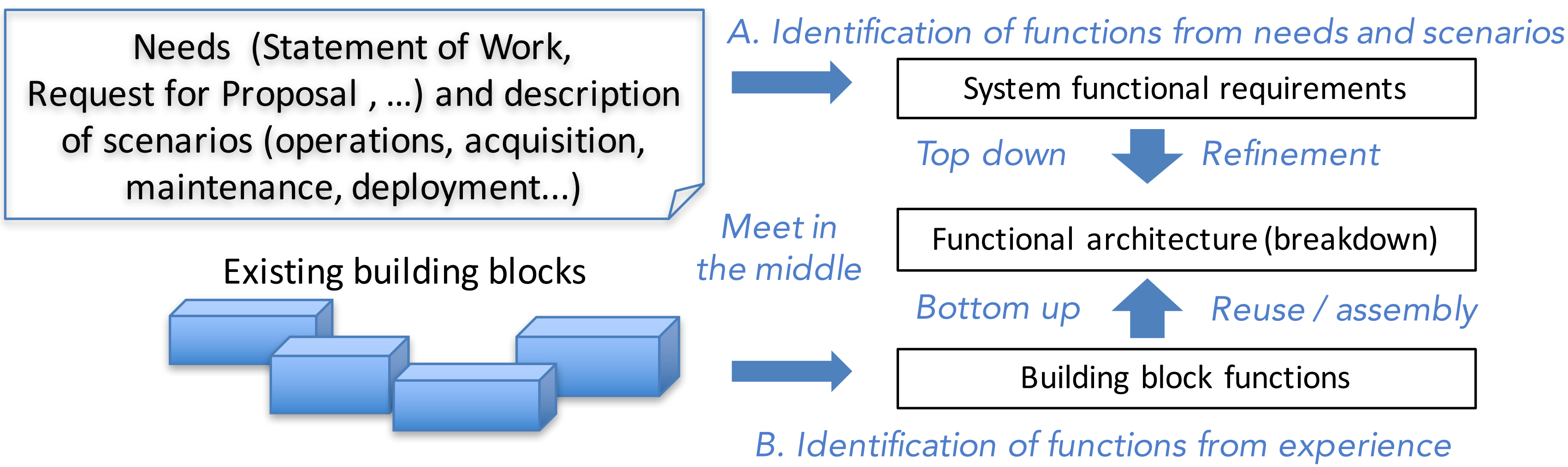
Generic solution based on SysML parametric equations



{http://www.omgsysml.org/Modeling-and-Simulation_of_CubeSat_Mission_v15-May_2013-Spangelo-Kim_Soremekun.pdf}

Case study – progress follow-up

- **We have now some refined vision of our product**
  - Could define "concept" solution: Hydrogen fuel battery, treatment product container, fine-grained nozzles, GPS signal…
  - Can identify functions associated to those building blocks
- **Can we build the right functional architecture?**
  - Probably not. Have to include operation level stakeholders and their needs and constraints on the whole system life cycle…



- **Example: missing the operational needs…**
  - 1 year was spent on design of a radar product. Validation on test bench (200 K€) revealed that the product did not really fit with operational scenarios. Supplier had to redesign it…
  - Conclusion: not enough efforts spent on identifying the business operations level stakeholders and understanding their real needs

ISO 15288 “Stakeholder needs and requirements definition” technical process can help

Stakeholder needs and requirements definition

Process purpose (ISO 15288:2015)

- *"The purpose of the Stakeholder Needs and Requirements Definition process is to define the stakeholder requirements for a system that can provide the capabilities needed by users and <u>other stakeholders</u> in a <u>defined</u> environment"*

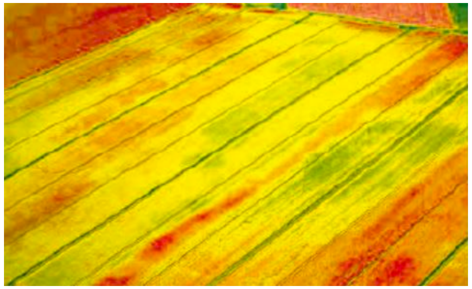
- **Steps**
  - Identify stakeholders of target system (operations level)
  - Elicit stakeholder needs
  - Initialize the Requirements Database
  - Develop the life cycle concepts (of system)
  - Generate the Stakeholder requirements specification (with traceability to business requirements)

Examples of Stakeholders of business operations level

- **Farmers interested by the product (operation)**
  - Paul who has 45 Ha of rape to treat
  - Mylène who has 25 Ha of corn to treat
- **Legal and regulations from France and Europe**
  - Usage constraints
  - Training and certification constraints (design, deployment)
- **UAV specialists and manufacturers**
  - Recommendations on structure, shapes, rotors…
- **Equipment suppliers**
  - Trends and figures on engines, batteries, pump, nozzles…

Paul and Mylène needs: examples

- **N1 (Paul): Optimize treatment**
  - He used an UAV to get field cartography
  - He would like system to adapt volume of product according to the field cartography



- **N2(Paul): Automated product filling**
  - Avoid manual filling of product (requires special equipment)
- **N3 (Mylène): Park the tank at 400 m from the target field to treat**
  - Avoid bringing the tank in a small path
- **N4 (Mylène): Treat early in the morning**
  - Get optimized hydrometric conditions

Regulatory constraints (France)

- **DEVA1528542A-12/17/2015**
  - Max altitude:150 m, far from people and houses
  - Category of UAV activities: « special » activities
  - Mass threshold: 150 Kgs
  - 4 categories/scenarios
    - - S-1 : less than 200 m for remote operator=> too limited for mission
    - **- S-2 : no people, maximum 1 Km from remote operator=> candidate**
    - - S-3 : people, can be seen with less than 100 m => out of scope
    - - S-4 : no people and not S1 nor S2 , but < 2 Kg => too limited
  - For S2, if more than 50 m then less than 2 Kgs => less than 50 m
  - Except for captive aerostats, UAV cannot be autonomous. Note: can still allow automatic flight (programmed before or during flight) but must remain under control of remote operator
  - Availability of documents: activity declaration, design certificate for security (people protection), activity manual, legal authorization

- **L.253-1 - NOR: AGRG0601345A – 09/21/2006 – Article 2**
  - Provide means to avoid treatment outside target field
  - Spray cannot be used if wind is greater or equal to 3 on Beaufort scale

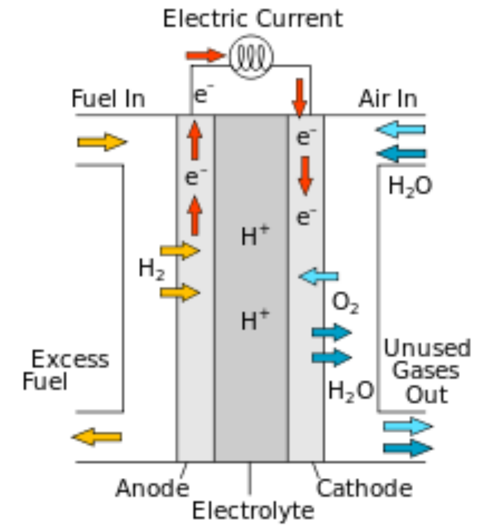
Recommendations from UAV specialists

- ONERA
  - http://www.onera.fr/sites/default/files/ressources_documentaires/cours-exposes-conf/LeTallec_RPAS_V2.pdf
  - …

- Yamaha R-MAX (long experience)
  - https://en.wikipedia.org/wiki/Yamaha_R-MAX

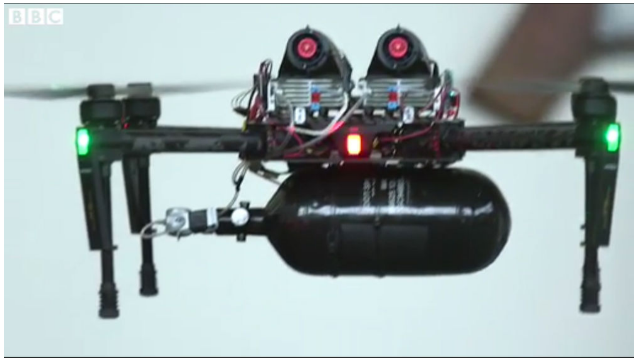
Trends from equipment suppliers

- **Fuel cell principle**
  - https://en.wikipedia.org/wiki/Fuel_cell



- **Hydrogen fuel cell battery**
  - http://rivaldrones.com/make-your-drone-go-farther-with-intelligent-energys-range-extender-technology

  - http://www.popsci.com/hydrogen-fuel-cell-powers-drone



Figures from equipment suppliers

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- **Nozzles variability**
  - Pump pressure (bar)
  - Drops density (µm)
  - Speed (km/h)
  - Spraying rate (l/mn)
  - Volume (l/ha)

	bar	TAILLE DES GOUTTELETTES 80°	TAILLE DES GOUTTELETTES 110°	DÉBIT D'UNE BUSE EN l/min	l/ha 50 cm 4 km/h	5 km/h	6 km/h	7 km/h	8 km/h	10 km/h	12 km/h	16 km/h	18 km/h	20 km/h	25 km/h	30 km/h	35 km/h
XR8001 XR11001 (100)	1,0	M	F	0,23	69,0	55,2	46,0	39,4	34,5	27,6	23,0	17,3	15,3	13,8	11,0	9,2	7,9
	1,5	F	F	0,28	84,0	67,2	56,0	48,0	42,0	33,6	28,0	21,0	18,7	16,8	13,4	11,2	9,6
	2,0	F	F	0,32	96,0	76,8	64,0	54,9	48,0	38,4	32,0	24,0	21,3	19,2	15,4	12,8	11,0
	2,5	F	F	0,36	108	86,4	72,0	61,7	54,0	43,2	36,0	27,0	24,0	21,6	17,3	14,4	12,3
	3,0	F	F	0,39	117	93,6	78,0	66,9	58,5	46,8	39,0	29,3	26,0	23,4	18,7	15,6	13,4
	4,0	F	VF	0,45	135	108	90,0	77,1	67,5	54,0	45,0	33,8	30,0	27,0	21,6	18,0	15,4
XR80015 XR110015 (100)	1,0	M	F	0,34	102	81,6	68,0	58,3	51,0	40,8	34,0	25,5	22,7	20,4	16,3	13,6	11,7
	1,5	M	F	0,42	126	101	84,0	72,0	63,0	50,4	42,0	31,5	28,0	25,2	20,2	16,8	14,4
	2,0	F	F	0,48	144	115	96,0	82,3	72,0	57,6	48,0	36,0	32,0	28,8	23,0	19,2	16,5
	2,5	F	F	0,54	162	130	108	92,6	81,0	64,8	54,0	40,5	36,0	32,4	25,9	21,6	18,5
	3,0	F	F	0,59	177	142	118	101	88,5	70,8	59,0	44,3	39,3	35,4	28,3	23,6	20,2
	4,0	F	F	0,68	204	163	136	117	102	81,6	68,0	51,0	45,3	40,8	32,6	27,2	23,3
XR8002 XR11002 (50)	1,0	M	M	0,46	138	110	92,0	78,9	69,0	55,2	46,0	34,5	30,7	27,6	22,1	18,4	15,8
	1,5	M	F	0,56	168	134	112	96,0	84,0	67,2	56,0	42,0	37,3	33,6	26,9	22,4	19,2
	2,0	M	F	0,65	195	156	130	111	97,5	78,0	65,0	48,8	43,3	39,0	31,2	26,0	22,3
	2,5	M	F	0,72	216	173	144	123	108	86,4	72,0	54,0	48,0	43,2	34,6	28,8	24,7
	3,0	F	F	0,79	237	190	158	135	119	94,8	79,0	59,3	52,7	47,4	37,9	31,6	27,1
	4,0	F	F	0,91	273	218	182	156	137	109	91,0	68,3	60,7	54,6	43,7	36,4	31,2
XR110025 (50)	1,0		M	0,57	171	137	114	97,7	85,5	68,4	57,0	42,8	38,0	34,2	27,4	22,8	19,5
	1,5		M	0,70	210	168	140	120	105	84,0	70,0	52,5	46,7	42,0	33,6	28,0	24,0
	2,0		F	0,81	243	194	162	139	122	97,2	81,0	60,8	54,0	48,6	38,9	32,4	27,8
	2,5		F	0,90	270	216	180	154	135	108	90,0	67,5	60,0	54,0	43,2	36,0	30,9
	3,0		F	0,99	297	238	198	170	149	119	99,0	74,3	66,0	59,4	47,5	39,6	33,9
	4,0		F	1,14	342	274	228	195	171	137	114	85,5	76,0	68,4	54,7	45,6	39,1
XR8003 XR11003 (50)	1,0	M	M	0,68	204	163	136	117	102	81,6	68,0	51,0	45,3	40,8	32,6	27,2	23,3
	1,5	M	M	0,83	249	199	166	142	125	99,6	83,0	62,3	55,3	49,8	39,8	33,2	28,5
	2,0	M	F	0,96	288	230	192	165	144	115	96,0	72,0	64,0	57,6	46,1	38,4	32,9
	2,5	M	F	1,08	324	259	216	185	162	130	108	81,0	72,0	64,8	51,8	43,2	37,0
	3,0	M	F	1,18	354	283	236	202	177	142	118	88,5	78,7	70,8	56,6	47,2	40,5
	4,0	M	F	1,36	408	326	272	233	204	163	136	102	90,7	81,6	65,3	54,4	46,6
XR8004 XR11004 (50)	1,0	C	M	0,91	273	218	182	156	137	109	91,0	68,3	60,7	54,6	43,7	36,4	31,2
	1,5	M	M	1,12	336	269	224	192	168	134	112	84,0	74,7	67,2	53,8	44,8	38,4
	2,0	M	M	1,29	387	310	258	221	194	155	129	96,8	86,0	77,4	61,9	51,6	44,2
	2,5	M	M	1,44	432	346	288	247	216	173	144	108	96,0	86,4	69,1	57,6	49,4
	3,0	M	M	1,58	474	379	316	271	237	190	158	119	105	94,8	75,8	63,2	54,2
	4,0	M	F	1,82	546	437	364	312	273	218	182	137	121	109	87,4	72,8	62,4
XR8005 XR11005 (50)	1,0	C	C	1,14	342	274	228	195	171	137	114	85,5	76,0	68,4	54,7	45,6	39,1
	1,5	C	M	1,39	417	334	278	238	209	167	139	104	92,7	83,4	66,7	55,6	47,7
	2,0	C	M	1,61	483	386	322	276	242	193	161	121	107	96,6	77,3	64,4	55,2
	2,5	M	M	1,80	540	432	360	309	270	216	180	135	120	108	86,4	72,0	61,7
	3,0	M	M	1,97	591	473	394	338	296	236	197	148	131	118	94,6	78,8	67,5
	4,0	M	M	2,27	681	545	454	389	341	272	227	170	151	136	109	90,8	77,8
XR8006 XR11006 (50)	1,0	C	C	1,37	411	329	274	235	206	164	137	103	91,3	82,2	65,8	54,8	47,0
	1,5	C	C	1,68	504	403	336	288	252	202	168	126	112	101	80,6	67,2	57,6
	2,0	C	M	1,94	582	466	388	333	291	233	194	146	129	116	93,1	77,6	66,5
	2,5	C	M	2,16	648	518	432	370	324	259	216	162	144	130	104	86,4	74,1
	3,0	C	M	2,37	711	569	474	406	356	284	237	178	158	142	114	94,8	81,3
	4,0	C	M	2,74	822	658	548	470	411	329	274	206	183	164	132	110	93,9
XR8008 XR11008 (50)	1,0	VC	C	1,82	546	437	364	312	273	218	182	137	121	109	87,4	72,8	62,4
	1,5	VC	C	2,23	669	535	446	382	335	268	223	167	149	134	107	89,2	76,5
	2,0	C	C	2,58	774	619	516	442	387	310	258	194	172	155	124	103	88,5
	2,5	C	C	2,88	864	691	576	494	432	346	288	216	192	173	138	115	98,7
	3,0	C	M	3,16	948	758	632	542	474	379	316	237	211	190	152	126	108
	4,0	C	M	3,65	1095	876	730	626	548	438	365	274	243	219	175	146	125
XR8010† XR11010†	1,0			2,28	684	547	456	391	342	274	228	171	152	137	109	91,2	78,2
	1,5			2,79	837	670	558	478	419	335	279	209	186	167	134	112	95,7
	2,0			3,23	969	775	646	554	485	388	323	242	215	194	155	129	111
	2,5			3,61	1083	866	722	619	542	433	361	271	241	217	173	144	124
	3,0			3,95	1185	948	790	677	593	474	395	296	263	237	190	158	135
	4,0			4,56	1368	1094	912	782	684	547	456	342	304	274	219	182	156
XR8015† XR11015†	1,0			3,42	1026	821	684	586	513	410	342	257	228	205	164	137	117
	1,5			4,19	1257	1006	838	718	629	503	419	314	279	251	201	168	144
	2,0			4,83	1449	1159	966	828	725	580	483	362	322	290	232	193	166
	2,5			5,40	1620	1296	1080	926	810	648	540	405	360	324	259	216	185
	3,0			5,92	1776	1421	1184	1015	888	710	592	444	395	355	284	237	203
	4,0			6,84	2052	1642	1368	1173	1026	821	684	513	456	410	328	274	235

{Teejet source}

Define the requirements database

- **Translate/reformulate needs into a set of concise requirements ("system shall …") traced to their originating needs**
  - St1: System shall optimize treatment rate according to different areas identified in digital field cartography -> traced to N1
  - St2: System shall support automated filling of treatment product -> traced to N2
  - St3: System shall allow parking the tank up to 300 m from target field-> traced to N3
  - St4: System shall allow treatment without any luminosity

- **Baseline will be defined with all elicited, analyzed, clarified and affordable requirements**

Develop System Life Cycle Concepts (1)

- **Operational concept (OpsCon)**
  - "user-oriented document that describes system characteristics of the to-be-delivered system from the user's viewpoint"
- **Example of operational scenario refinement (from mission analysis)**
  - Requisite: a flight plan exists, optimized for field and container is filled
  - Step 1: activate UAV (performs check-in tests) and check wind
  - Step 2: load configuration including flight plan through USB key
  - Step 3: launch UAV for treatment: UAV treats until product is low (sensor).
  - Step 4: refill product
  - Step 5: resume mission: UAV continues to treat until end of flight plan.
  - Step 6: monitor mission with position feedback on augmented reality screen in parallel with UAV flight.
  - Alternate scenarios:
    - 4.C. Wind becomes too strong. UAV shall stop treating.
    - 5.A Loss of communication
    - 5.B inconsistent position detected on screen => remote operator takes back control.
  - HMI mockup for remote control software application

Develop System Life Cycle Concepts (2)

- **Acquisition concept**
  - "Describes the way the system will be acquired including aspects such as stakeholder engagement, requirements definition, design, production, and verification."

- **Example of acquisition scenarios**
  - Flight plan will be produced by a dedicated software application able to take a digital map as input and export it to an XML file that can then be loaded on UAV through USB key and checked with following consistency rules: …
  - UAV behavior shall be simulated so that remote operator can train on its control. Following control events can be injected: …
  - Battery shall be verified against its specification through the following tests:…
  - Integration of pump and nozzles will be verified against the following tests: ...

Develop System Life Cycle Concepts (3)

- **Deployment concept**
  - "Describes the way the system will be validated, delivered, and introduced into operations, including deployment considerations when the system will be integrated with other systems that are in operation and/or replace any systems in operation.

- **Examples of validation scenarios**
  - Validation scenario 1: start following a flight plan on a small field with no spray loaded => check that flight guidance is OK and that position sent back is OK.
  - Validation scenario 2: Follow a flight plan with small volume of product to check if UAV detects appropriately the end of product and can then come back to its last treatment position
  - Validation scenario 3: Follow a flight plan and simulate wind after 5 minutes of treatment to check that UAV stops treating and lands immediately.

Develop System Life Cycle Concepts (4)

- **Support concept**
  - "Describes the desired support infrastructure and manpower considerations for supporting the system after it is deployed"

- **Examples of scenarios**
  - When battery is low, a signal will be sent to the remote operator control application so that he/she can prepare to reload it.
  - When treatment product is low, a signal will be sent to the remote operator control application…
  - Maintenance schedule table is available in a digital format for all UAV parts with mention of the suggested date for replacement.

Develop System Life Cycle Concepts (5)

- **Retirement concept**
  - "Describes the way the system will be removed from operation and retired, including the disposal of any hazardous materials used in or resulting from the process and any legal obligations".
- **Examples of scenarios**
  - The following procedure explains how to dispose UAV and its parts with special mention on battery: …

Analyze and negotiate requirements

- **St1: System shall optimize treatment rate according to different areas identified in digital field cartography**
  - Requires variability in the speed of the treatment pump or in nozzles
  - Important to get very detailed precision (key for business): **accepted**

- **St2: System shall support automated filling of treatment product**
  - Requires flexible pipe able to "connect" to the tank and pump spray and very precise stationary flight on top of tank during operation
  - Requires many studies: **negotiation to reject that requirement for first release**

Analyze and negotiate requirements

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- **St3: System shall allow parking the tank up to 300m from target field**
  - UAV will have to fly on top of another field before reaching target field ➔ product container shall resist in case of UAV crash (avoid pollution)
  - Robustness already required by regulations => no extra cost: **accepted**

- **St4: System shall allow treatment without any luminosity**
  - Requires infra red camera or other system to check position
  - Already identified by business (more attractive than other solutions): **accepted**

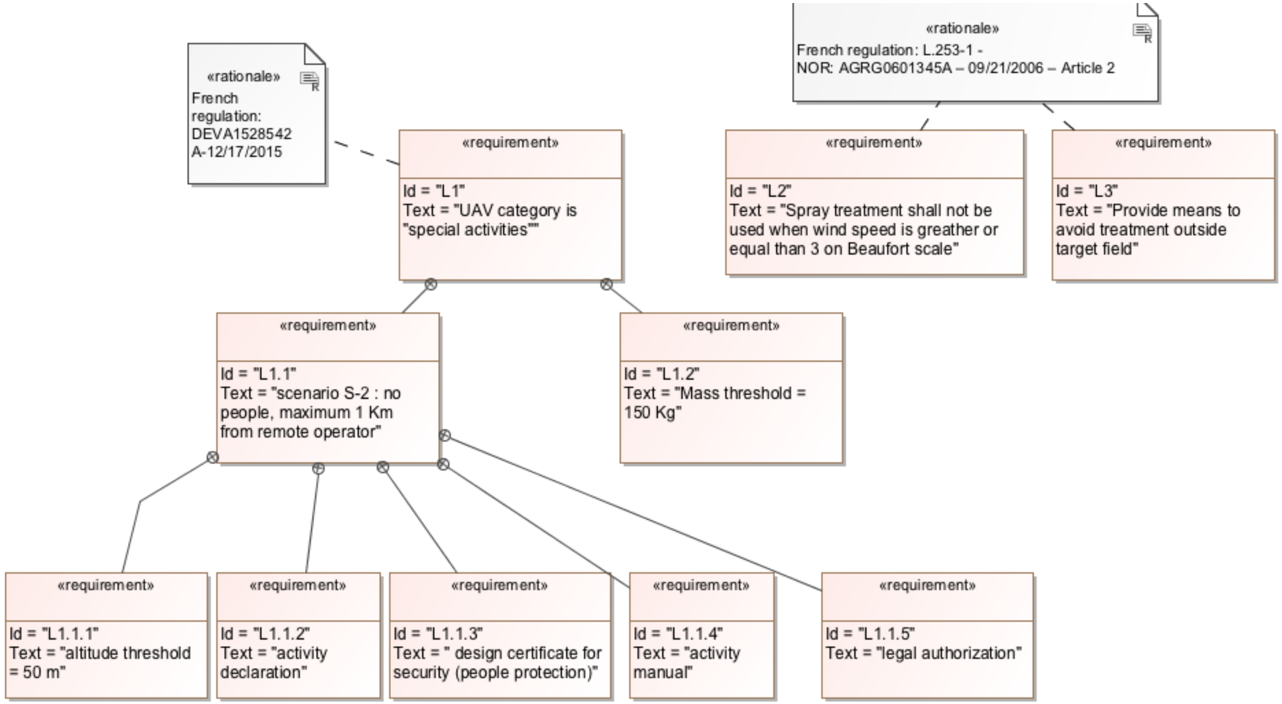
Benefits of models for

Stakeholder needs and requirements definition

Incremental decomposition of sentences

Id	Text
L1	UAV category is "special activities"
L1.1	scenario S-2 : no people, maximum 1 Km from remote operator
L1.1.1	altitude threshold = 50 m
L1.1.2	activity declaration
L1.1.3	design certificate for security (people protection)
L1.1.4	activity manual
L1.1.5	legal authorization
L1.2	Mass threshold = 150 Kg
L2	Spray treatment shall not be used when wind speed is greather or equal than 3 on Beaufort scale
L3	Provide means to avoid treatment outside target field

Decomposition of constraints/requirements (SysML Requirements diagram or table).



Note: those “requirements” are still “poor quality” requirements (need reworking) but it is a first refinement step with traceability

Guidance in structuration of needs

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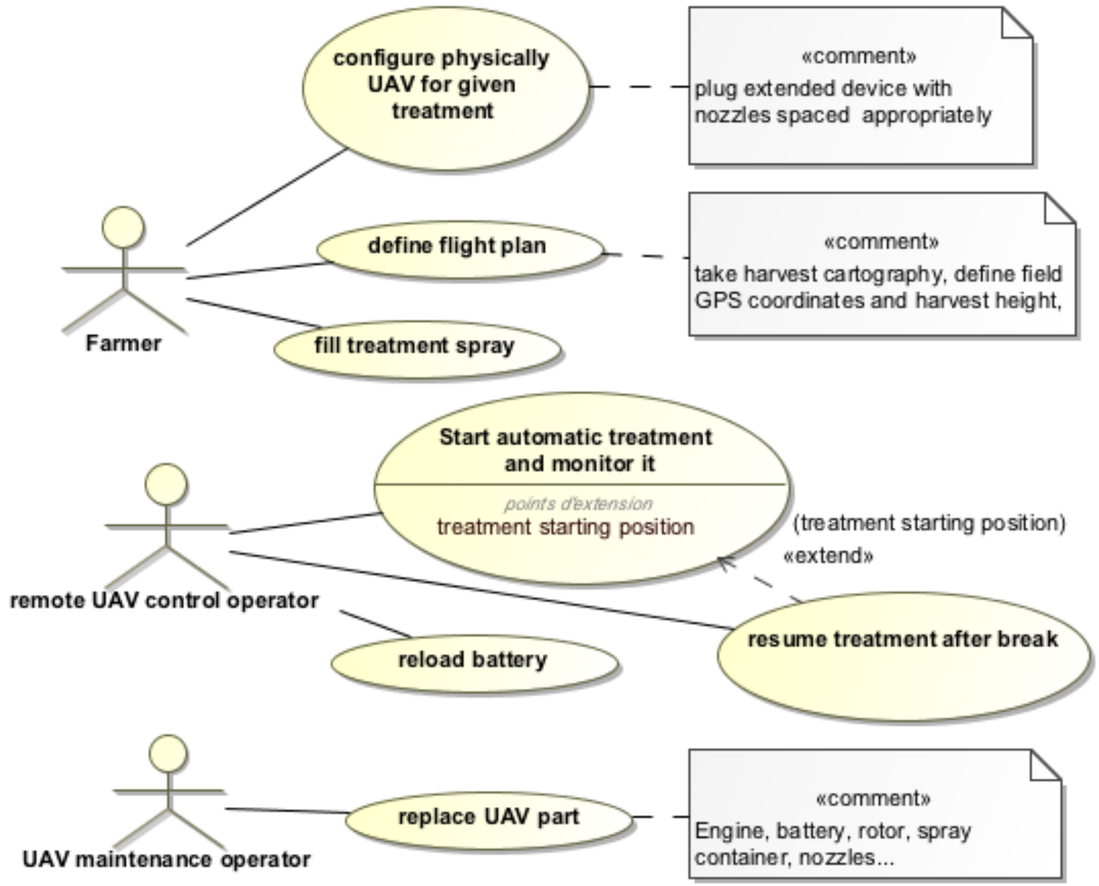
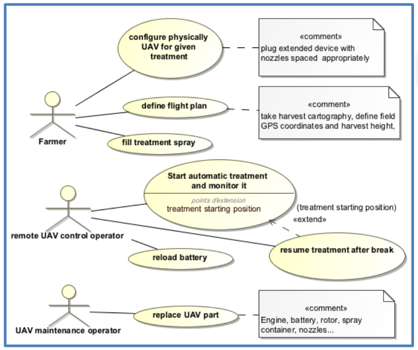
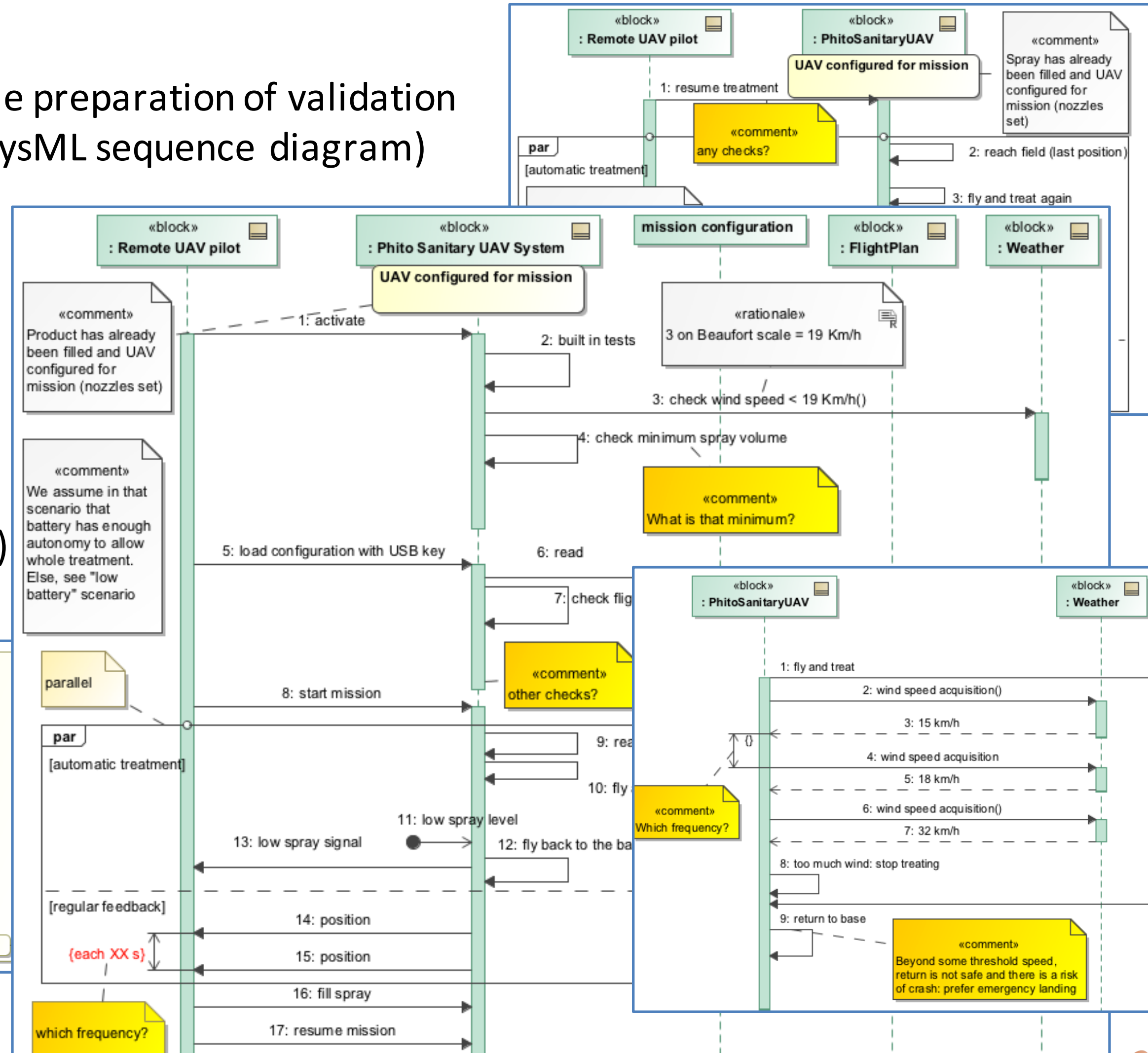
Main functionalities for different system stages of system life cycle and associated roles (SysML use cases diagram)



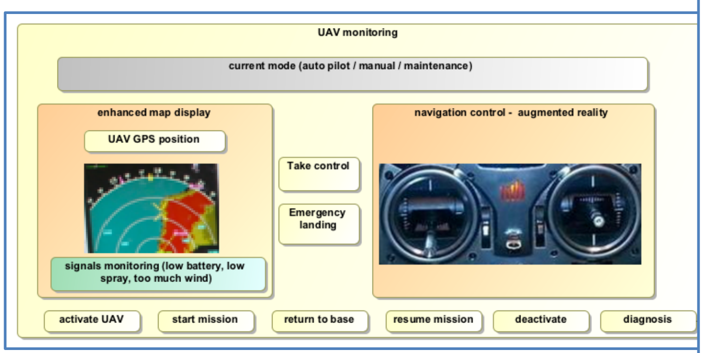
Helps capturing scenarios and discussing with stakeholders on missing points / issues



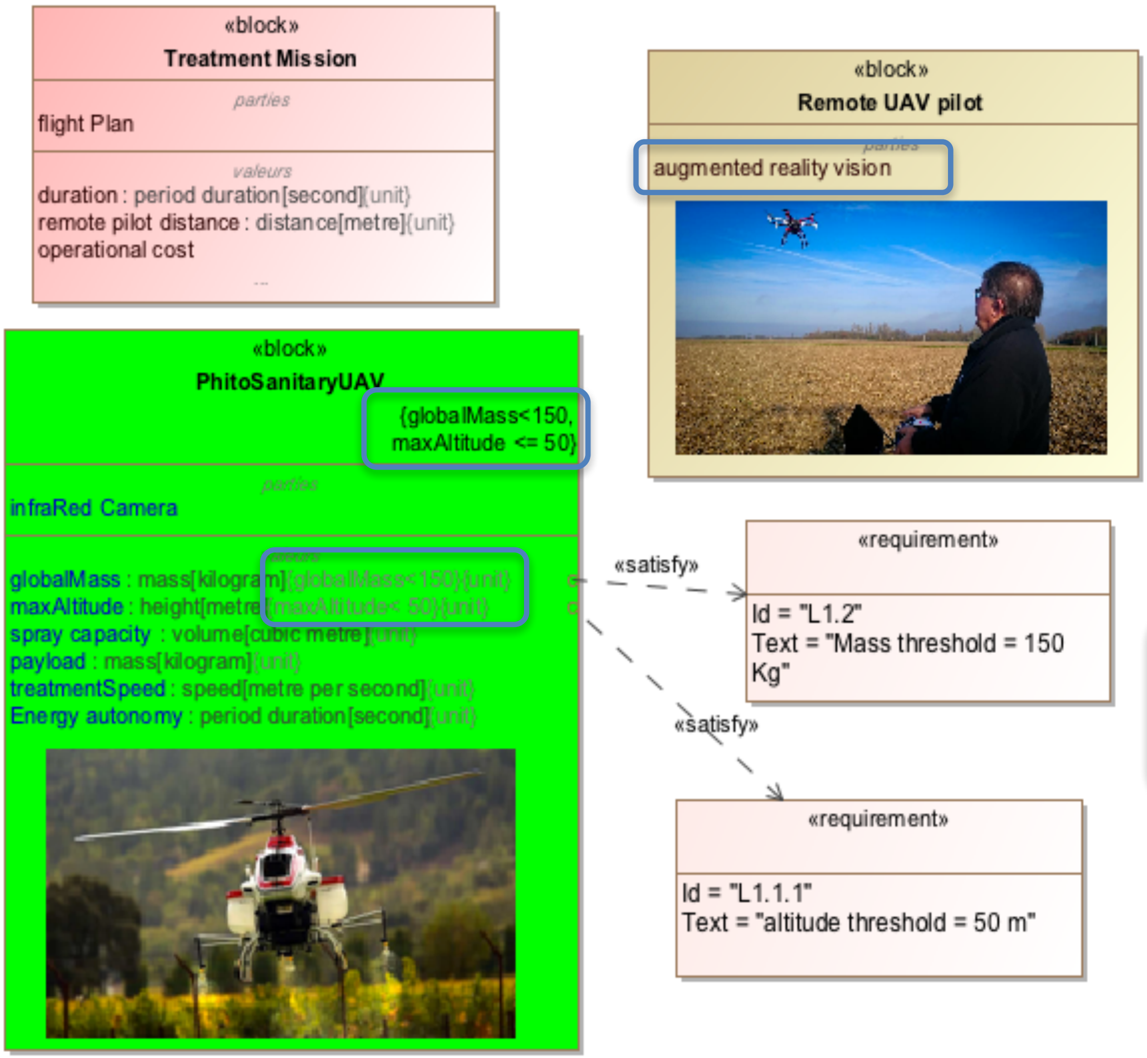
Agile preparation of validation (SysML sequence diagram)



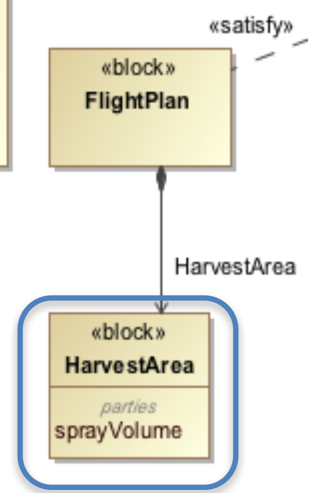
HMI definition (structure and navigation) (SysML state machine diagram)



Consistent refinement of operational context from mission analysis

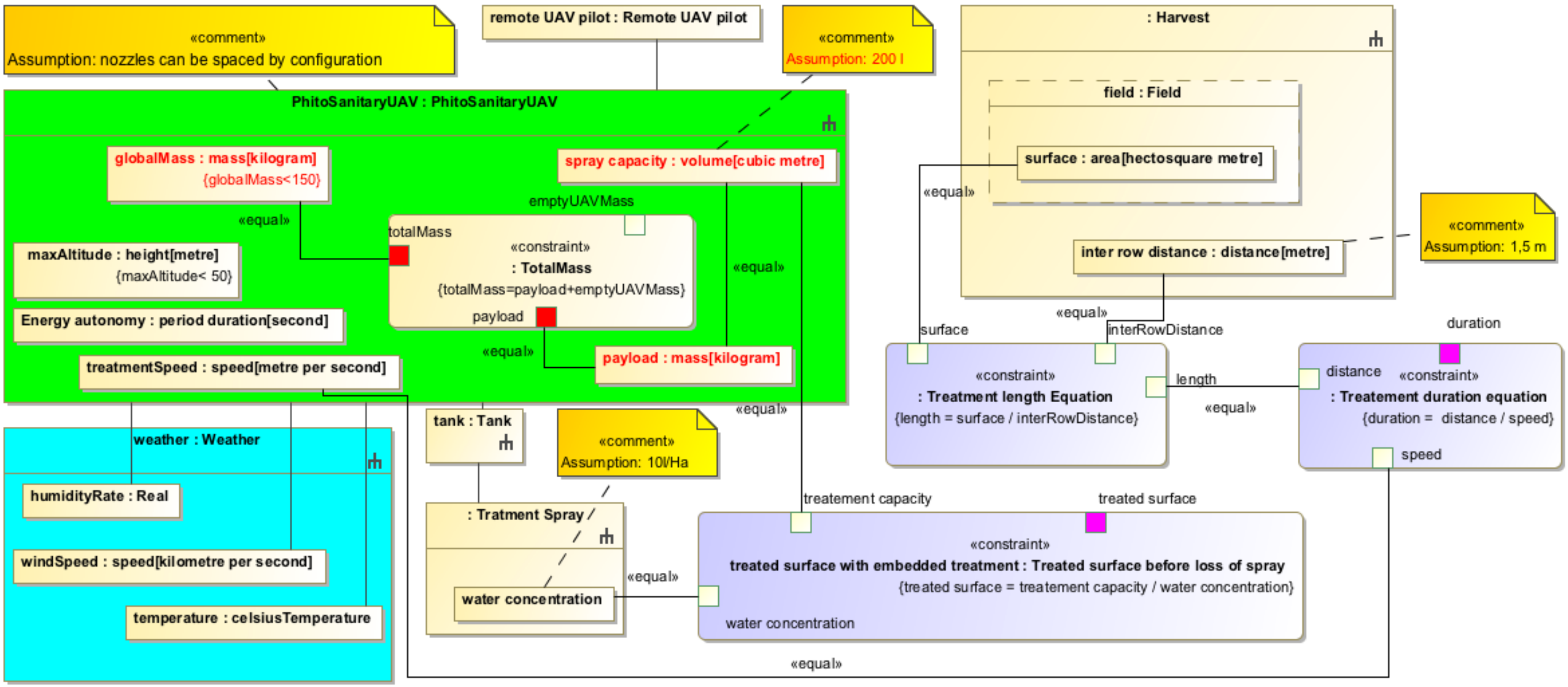


Mission analysis model is completed / modified – result can be compared to initial mission analysis model (differences between versions)



Centralization of constraints: help detecting inconsistencies

Ex: product capacity assumption can not reach 200 l because it would exceed maximum global UAV mass, limited to 150 Kg by regulation …



Case study – progress follow-up

- **Current state**
  - Stakeholder needs and constraints captured and feasible/affordable and strategic requirements elicited
  - Needs transformed and constraints transformed into requirements
  - All identified missing points and inconsistencies discussed
  - Baseline defined with a set of stakeholder requirements

- **Do we have all system requirements to engage on?**
  - No: stakeholder requirements baseline lists expectations and constraints on the future system. There is no guarantee that this set is fully consistent and can be satisfied by a technical solution within reasonable quality, schedule and cost. System supplier can not take that risk.
  - So system supplier writes and engages on their own system requirements (meeting all stakeholders requirements)

ISO 15288 "System requirements definition" process can help

System requirements definition

Process purpose (ISO 15288:2015)

- **"The purpose of the System Requirements Definition process is to transform the stakeholder, user-oriented view of desired capabilities into a technical view of a solution that meets the operational needs of the user."**

- **Steps (iterative, recursive, top-down and bottom-up)**
  - Define system Requirements (functional and non functional)
  - Analyze system requirements
  - Generate the System Requirements Specification (SyRS)

Define functional and performance requirements

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- **Identify the required system functions:**
  - Fly from one position to another position with given speed
  - Fly from one position and follow a flight plan with given speed
  - Treat = open nozzles and inject spray with a given rate
  - …

- **Specify functional boundaries and performance**
  - Flight plan definition given by FP.XSD grammar
  - Maximum size of flight plan data is 200 Mo
  - 30 s maximum to load flight plan on UAV from USB key
  - 50 ms maximum to read next position of flight plan in "follow flight plan" function
  - Frequency of feedback position: each 200 ms
  - …

Define other system requirements

- ## Sugestion - ISO 29148:2011 (Requirement Engineering)

http://sebokwiki.org/wiki/System_Requirements

Types of System Requirement	Description
Functional Requirements	Describe qualitatively the system functions or tasks to be performed in operation.
Performance Requirements	Define quantitatively the extent, or how well, and under what conditions a function or task is to be performed (e.g. rates, velocities). These are quantitative requirements of system performance and are verifiable individually. Note that there may be more than one performance requirement associated with a single function, functional requirement, or task.
Usability Requirements	Define the quality of system use (e.g. measurable effectiveness, efficiency, and satisfaction criteria).
Interface Requirements	Define how the system is required to interact or to exchange material, energy, or information with external systems (external interface), or how system elements within the system, including human elements, interact with each other (internal interface). Interface requirements include physical connections (physical interfaces) with external systems or internal system elements supporting interactions or exchanges.
Operational Requirements	Define the operational conditions or properties that are required for the system to operate or exist. This type of requirement includes: human factors, ergonomics, availability, maintainability, reliability, and security.
Modes and/or States Requirements	Define the various operational modes of the system in use and events conducting to transitions of modes.
Adaptability Requirements	Define potential extension, growth, or scalability during the life of the system.
Physical Constraints	Define constraints on weight, volume, and dimension applicable to the system elements that compose the system.
Design Constraints	Define the limits on the options that are available to a designer of a solution by imposing immovable boundaries and limits (e.g., the system shall incorporate a legacy or provided system element, or certain data shall be maintained in an online repository).
Environmental Conditions	Define the environmental conditions to be encountered by the system in its different operational modes. This should address the natural environment (e.g. wind, rain, temperature, fauna, salt, dust, radiation, etc.), induced and/or self-induced environmental effects (e.g. motion, shock, noise, electromagnetism, thermal, etc.), and threats to societal environment (e.g. legal, political, economic, social, business, etc.).
Logistical Requirements	Define the logistical conditions needed by the continuous utilization of the system. These requirements include sustainment (provision of facilities, level support, support personnel, spare parts, training, technical documentation, etc.), packaging, handling, shipping, transportation.
Policies and Regulations	Define relevant and applicable organizational policies or regulatory requirements that could affect the operation or performance of the system (e.g. labor policies, reports to regulatory agony, health or safety criteria, etc.).
Cost and Schedule Constraints	Define, for example, the cost of a single exemplar of the system, the expected delivery date of the first exemplar, etc.

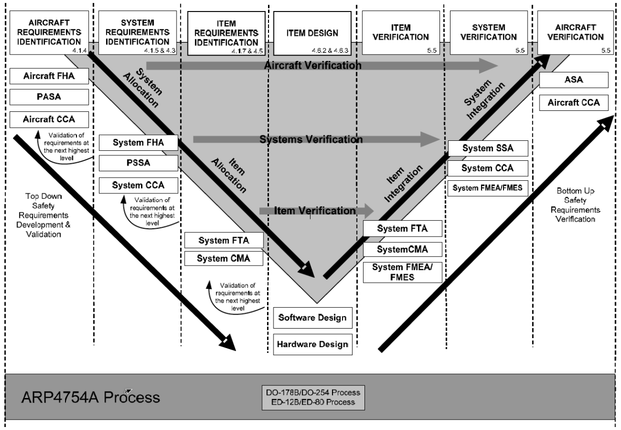
Examples of non functional requirements

- **Unavoidable constraints from stakeholders:**
  - Ex: flight plan definition shall be loaded by USB key
  - Ex: Prevent opening nozzles if wind is over 19 Km/h or if UAV is outside the target field to treat
  - Ex: Spraying rate shall be adaptable to flight plan area
  - …

- **Requirements deduced from risks and hazards analysis**
  - Examples of risks: loss of GPS signal, loss of remote control communication, bad sensing of wind speed, bad sensing of low battery…
  - Example of safety procedure: *"after 3 missing GPS signals, UAV shall warn remote operator, suspend its mission and land below its current position"*

Examples of additional constraints

- **Standards: can come from quality, engineering policies…**
  - Ex: SAE ARP4754a for Aircraft and avionic systems



- **Design drivers: includes reuse/product line, skills, knowledge/training…**
  - Ex: Promising studies on hydrogen fuel battery
  - Ex: follow recommendations from ONERA partner on aerodynamics
  - Ex: reuse of TK3 engine amongst 4 programs

- **Physical limits**
  - Ex: 150 Kg maximum

Analyze system requirements (1)

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- **Ensure that set of requirements is complete**
  - Cover all stakeholder requirements of the baseline
- **Ensure that set of requirements is feasible**
  - Identify technologies and products, define assumptions, perform analysis and constraint evaluation/solving
- **Ensure integrity of the set of requirements**
  - Ensure that one requirement does not break integrity of others
  - Example: "*Remote control operator shall have means to take control on UAV and continue treatment manually*" can potentially break integrity of requirement "*UAV shall prevent opening nozzles outside the target field to treat*"

  ➔ have to refine "take control" scope.

Analyze systems requirements (2)

- **Demonstrate that system requirements meet stakeholder requirements with accuracy**
  - Ex: "*when wind speed is measured between 19 km/h and 30 km/h, UAV shall stop treating and return to base*" => Need to add condition "with nozzles closed" to really match "*treatment by spray shall not be used when wind speed is over 3 on Beaufort scale*".

- **Negotiate modifications to solve issues**
  - Ex: "take control" will be limited to "flight management without treatment" to avoid any risk of bad command on treatment

- **Define verification criteria**
  - Ex: to verify "Fly from one position to another position with given speed" we will use feedback GPS positions:
  - Assert that feedback positions are aligned with start and destination positions (straight forward flight)
  - Assert that distance between two feedback positions is the same as given speed * feedback period with maximum of 5% error

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- Top-down and bottom-up process, strongly connected with "Architecture Definition" process

Needs (Statement of Work, Request for Proposal , ...) and description of scenarios (operations, acquisition, maintenance, deployment...)

A. Identification of functions from needs and scenarios

System functional requirements

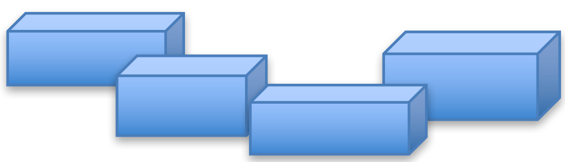
Top down — *Refinement / Flow down*

Meet in the middle

Functional architecture (breakdown)

Bottom up — *Reuse / assembly*

Existing building blocks



Building block functions

B. Identification of functions from experience

- Goal is to decompose high level functions, interfaces and performance down to hardware and software items while integrating functions from reused blocks

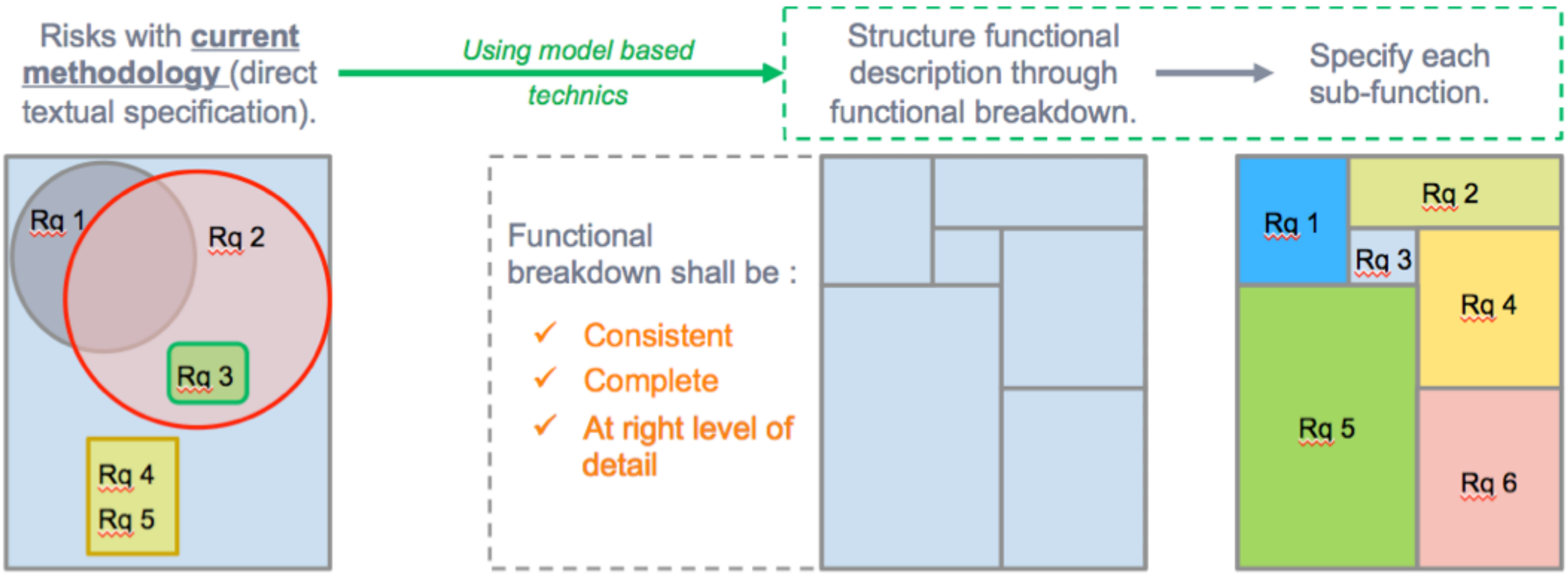
Benefits of models for *System Requirements Definition*

Reduces time to reach "good quality" on system requirements

- Systems requirements definition is complex and takes a lot of time in verifications (completeness, correctness, consistency)

- Modelling technic with appropriate approach can remove a lot of verifications with "correct by construction" functional breakdown

{Jean Duprez, Airbus, 12/2014}



Helps synthetizing all signals / events and high level system behavior view

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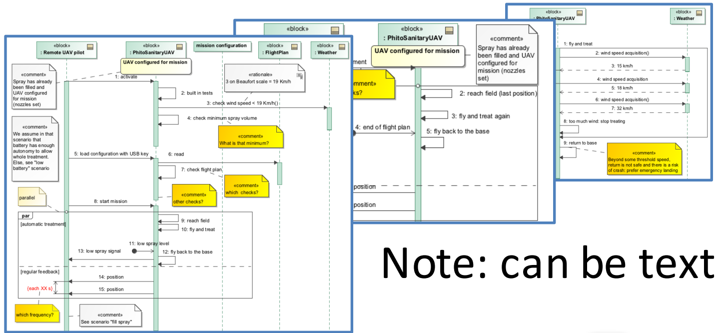
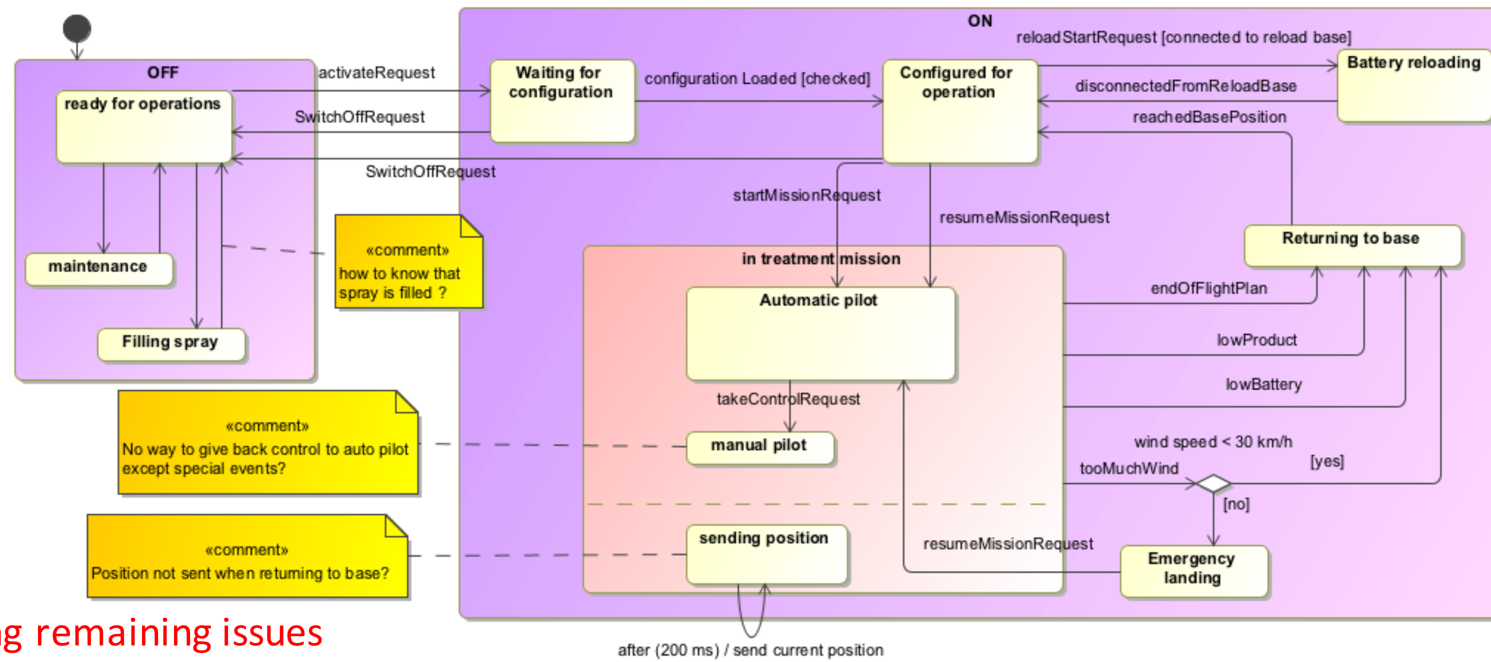


Note: can be textual

- 3. system Requirements
  - constraints – equations
  - interfaces
  - required functions and performance
  - signals- events
    - activateRequest
    - completeReload
    - configurationLoaded
    - disconnectedFromReloadBase
    - emergencyLandingRequest
    - endOfFlightPlan
    - lowBattery
    - lowProduct
    - reachedBasePosition
    - releaseControlRequest
    - reloadStartRequest
    - resumeMissionRequest
    - returnToBaseRequest
    - startMissionRequest
    - SwitchOffRequest
    - takeControlRequest
    - tooMuchWind

High level signals / events extracted from scenarios

Centralized view of high level behavior (SysML state machine)



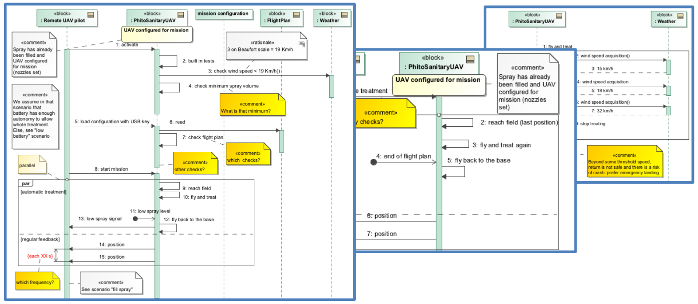
Helps detecting remaining issues

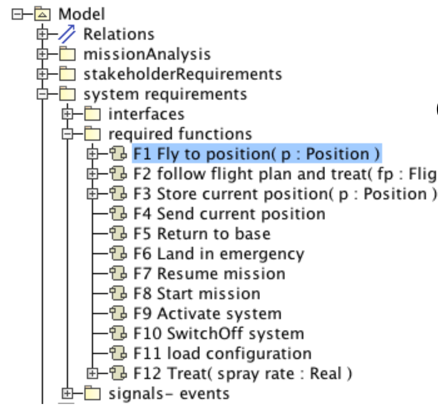
Return from industrial experience

- **Context / modelling opportunity**
  - First review of customer requirements about avionic system
  - Decision taken by system team to experiment use of models in order to formalize requirements related to HMI and interactions .
- **Results**
  - Took 0,5 day (modeling expert) to formalize about 30 requirements
  - State machines were used to describe screen areas and interactions
  - Block diagrams were used to describe structured displayed data
  - Modelling activity raised 5 questions on ambiguous requirements and highlighted 3 missing requirements, not identified previously

Modelling improved customer requirements analysis
(semantic clarification and completeness)

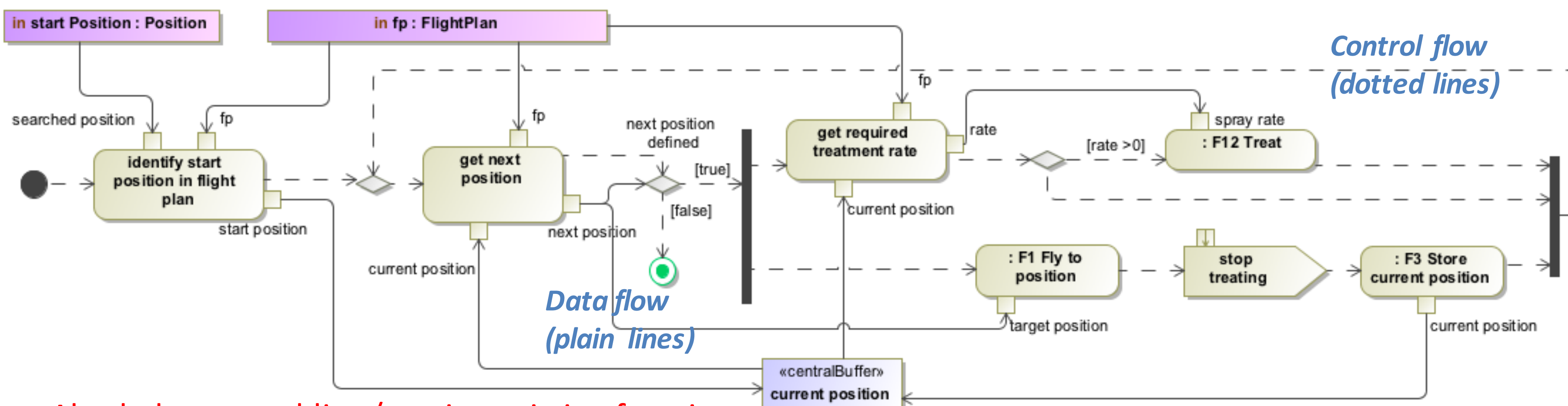
Helps identifying main functions, and defining and refining them consistently





High level functions extracted from scenarios

Functional refinement consistent by construction (interfaces, flow, control logics) and fully defined (activation, decisions, end…)



Also helps assembling/reusing existing functions

Return from industrial experience

- **Context / modelling opportunity**
  - Display of engine parameters with derived computations
  - 4 weeks before delivery of System Requirements Review
  - Use of models to check completeness of system requirements

- **Results**
  - 3 days (efforts) by modeling expert to formalize functional behavior from specification with 3h of functional expert support
  - Activity diagrams used to describe functional flow (data /control)
  - Modelling activity raised 10 questions about function sequencing, synchronization and activation conditions

Modelling improved system requirements definition (completeness and consistency)

Helps checking feasibility of system requirements with associated performance

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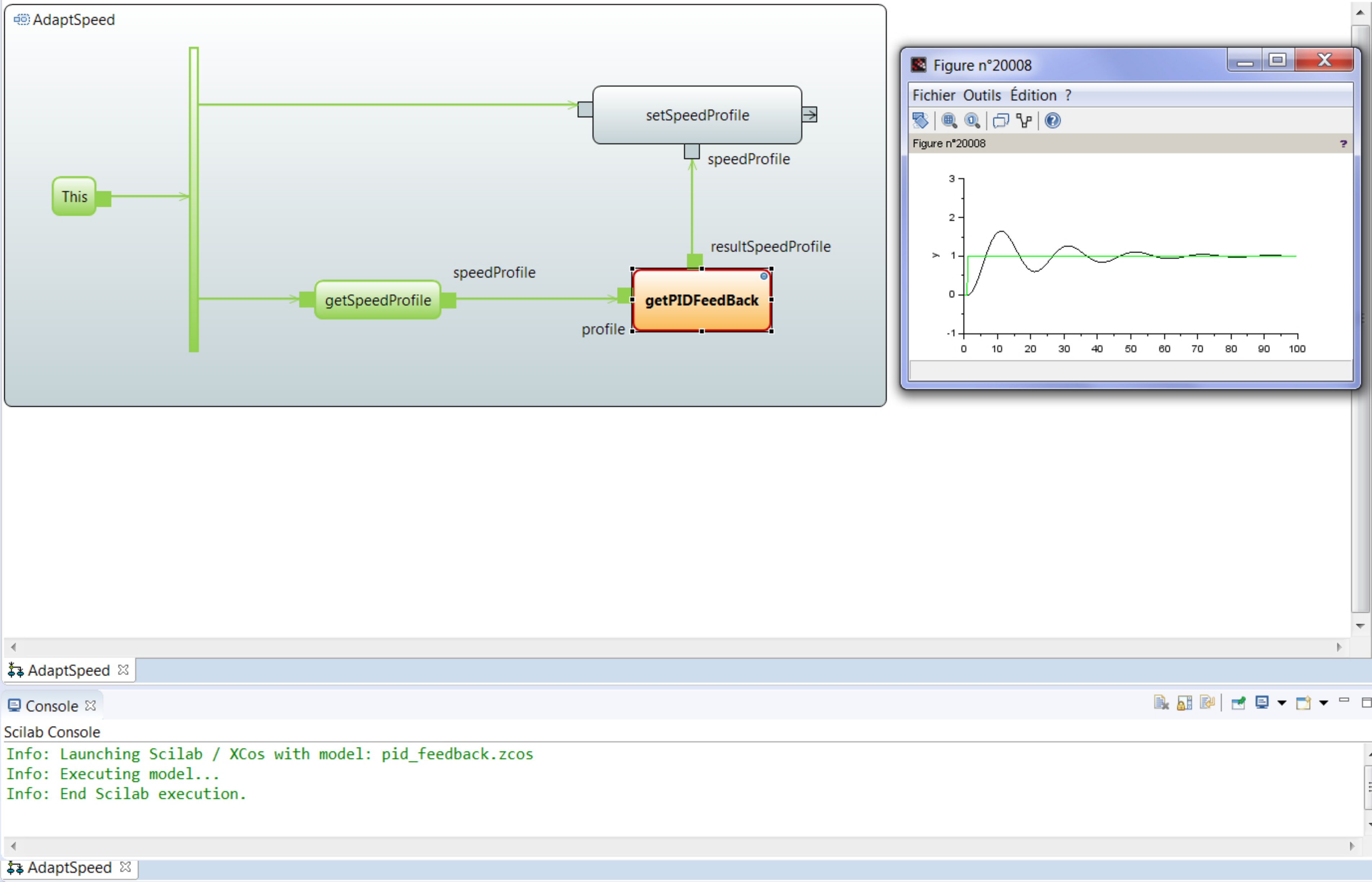


System Architecture definition

Process purpose (ISO 15288:2015)

- *"The purpose of the Architecture Definition process is to generate system architecture alternatives, to select one or more alternative(s) that frame stakeholder concerns and meet system requirements, and to express this in a set of consistent views"*

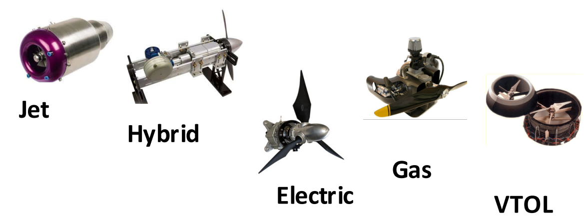
- **Main activities**
  - Identify useful architecture view points
  - Develop models and views for candidate architectures
  - Identify interface and emergent properties
  - Assess architectures (in connection with analysis process)

Separation of architecture and design

- **Different focuses**
  - Architecture focuses on system breakdown into system elements
  - Design focuses on technologies able to support implementation

- **Different abstraction levels**
  - Architecture is more abstract and more conceptual
  - Design provides physical solutions to architectural entities

- **Interests of separation**
  - Can then change design for one of the system elements without completely breaking architecture
  - Flexibility



Some useful views of architecture (1)

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Logical architecture views

- **Functional architecture view**
  - *"set of functions and sub functions that define the transformations performed by the system to complete its mission"*
- **Behavioral architecture view**
  - *"arrangement of functions and their sub-functions as well as interfaces (inputs and outputs) that defines the execution sequencing, conditions for control or data-flow, and performance level necessary to satisfy the system requirements (ISO/IEC 26702 2007.*
  - *A behavioral model can be described as* a set of inter-related scenarios of functions and/or operational modes."
- **Temporal architecture view**
  - *"classification of the functions of a system that is derived according to the frequency level of execution. Temporal architecture includes the definition of synchronous and asynchronous aspects of functions"*

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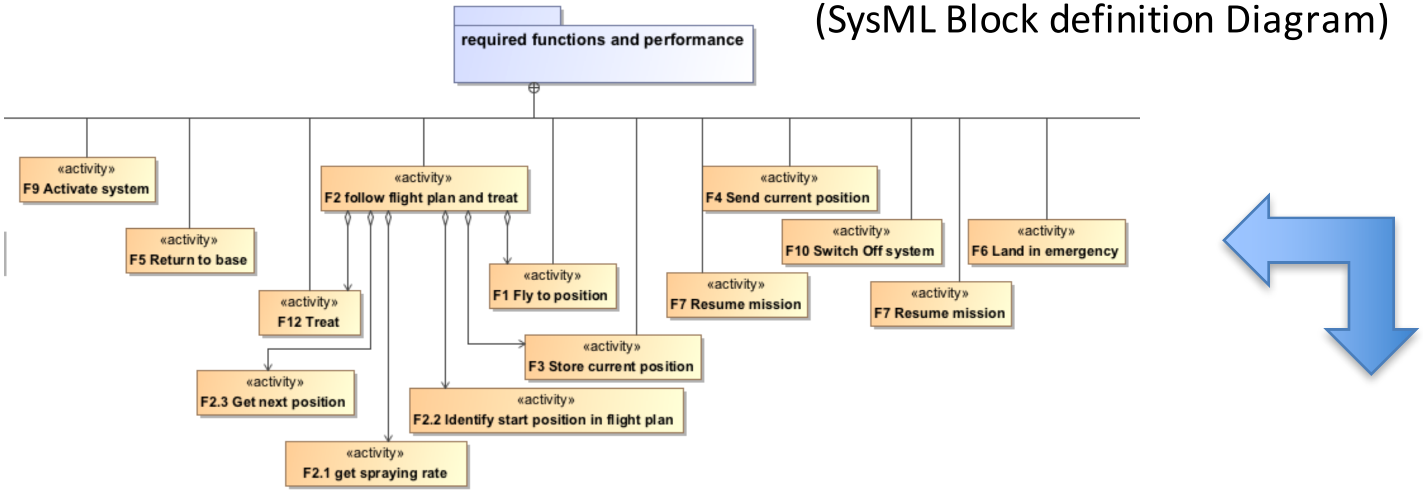
- **Physical architecture view**
  - "An arrangement of physical elements, (system elements and physical interfaces) that provides the solution for a product, service, or enterprise. It is intended to satisfy logical architecture elements and system requirements ISO/IEC/IEEE 26702 (ISO 2007). It is implementable through technological system elements.

Table 1. Types of System Elements and Physical Interfaces. (SEBoK Original)

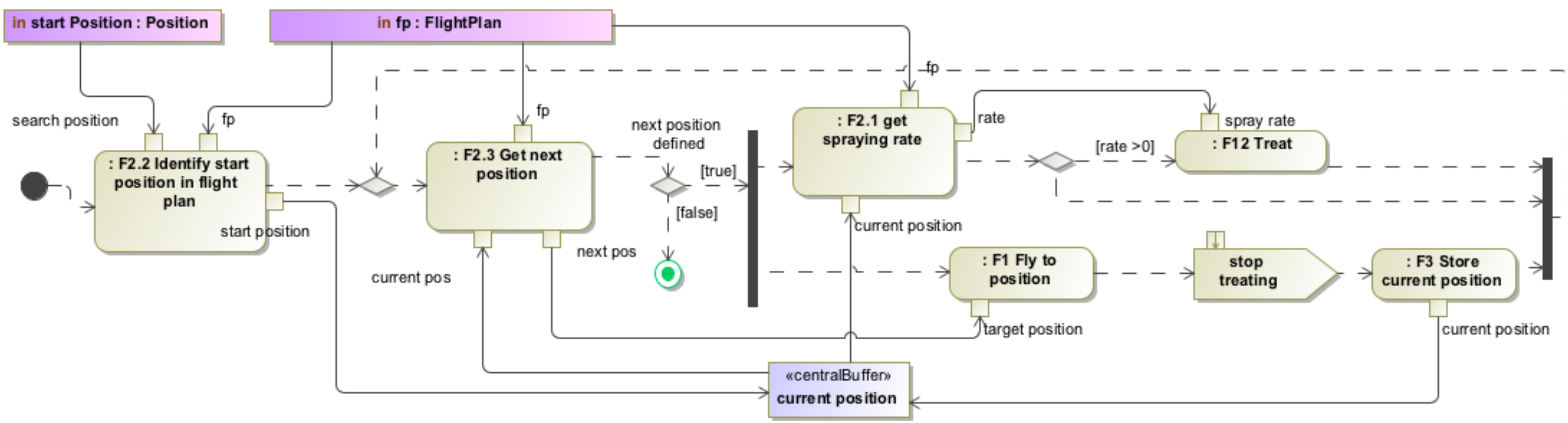
Element	Product System	Service System	Enterprise System
System Element	• Hardware Parts (mechanics, electronics, electrical, plastic, chemical, etc.) • Operator Roles • Software Pieces	• Processes, Data Bases, Procedures, etc. • Operator Roles • Software Applications	• Corporate, Direction, Division, Department, Project, Technical Team, Leader, etc. • IT Components
Physical Interface	* Hardware Parts, Protocols, Procedures, etc.	* Protocols, Documents, etc.	* Protocols, Procedures, Documents, etc.

Examples of views (1)

Functional architecture structural view (incremental definition): Functions breakdown (SysML Block definition Diagram)



Scenario of functions with both control and energy/data flow



Examples of views (2)

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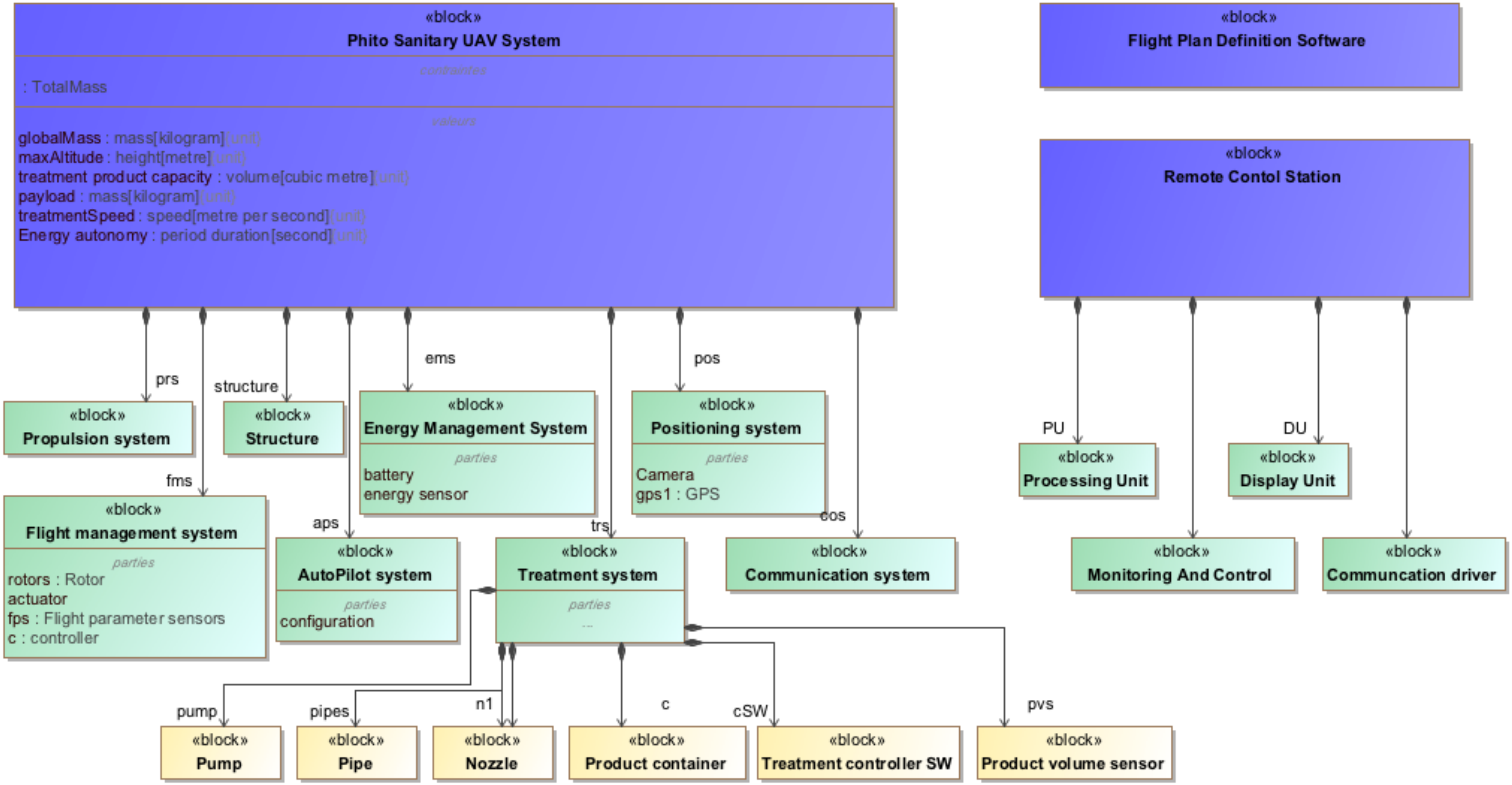
Physical architecture structural view (incremental definition): system elements breakdown (SysML Block definition Diagram)



Examples of views (3)

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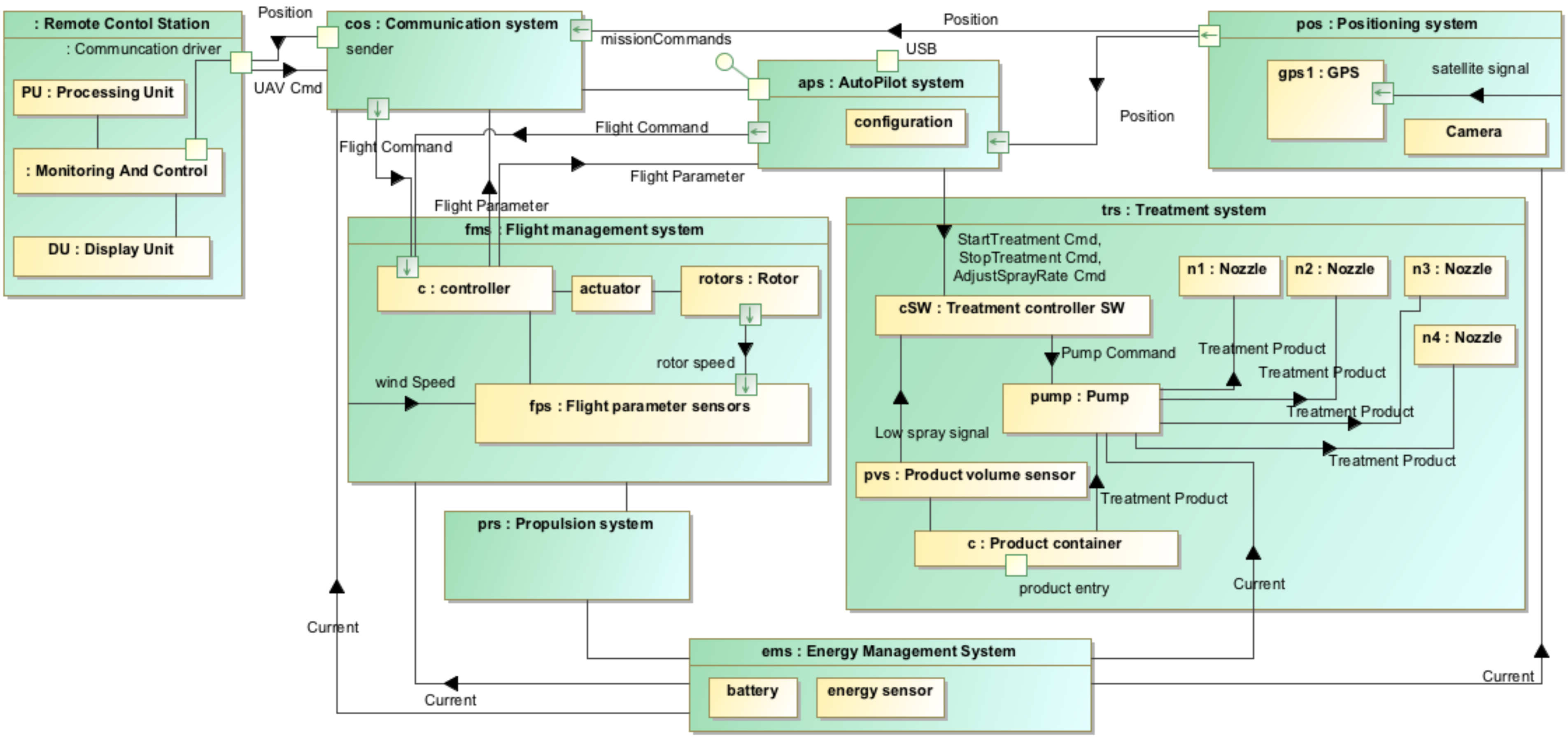
Physical architecture communication view: system elements occurrences, physical links and conveyed items (SysML Internal Block Diagram)



Examples of views (4)

Allocation of functions on system elements and physical interfaces
(SysML Allocation table)

Legend
↗ Allocate

	4. system Architecture	Flow types	hardware elem...	Phito Sanitary UA...	phy	Electric Cable	Pipe	software elem...	sub systems and equi	AutoPilot syst...	Communicatio...	Energy Manag...	Flight manage...	Positioning sy...	Propulsion sys...	Remote Conto...	Treatment sys...
required functions						1	1			9	1	3	2	2	2	1	1
F1 Fly to position(p : Position)(context Flight management system)	1								1				↗				
F2 follow flight plan and treat(fp : FlightPlan, start Position : Position)(context AutoP	1								1	↗							
F2.1 get Requirement rate(fp, rate, current position)(context AutoPilot system)	1								1	↗							
F2.2 Identify start position in flight plan(fp : FlightPlan, search position, start pos	1								1	↗							
F2.3 Get next position(fp, current pos, next pos : Position)(context AutoPilot sys	1								1	↗							
F3 Store current position(p : Position)(context AutoPilot system)	1								1	↗							
F4 Send current position(pos : Position)(context Communication system)	1								1		↗						
F5 Return to base(context AutoPilot system)	1								1	↗							
F6 Land in emergency(context Flight management system)	1								1				↗				
F7 Resume mission(context AutoPilot system)	1								1	↗							
F8 Start mission(context AutoPilot system)	1								1	↗							
F9 Activate system(context Energy Management System)	1								1			↗					
F10 Switch Off system(context Energy Management System)	1								1			↗					
F11 load configuration(conf : Configuration)(context AutoPilot system)	1								1	↗							
F12.1 Carry treatment product(tpIn : Treatment Product, tpOut Treatment Product	1				1		↗										
F12 Treat(spray rate : Real)(context Treatment system)	1								1								↗
F15 Acquire GPS signal(signal : GPS Signal)(context Positioning system)	1								1					↗			
F20.1 Carry current(cIn : Current, cOut : Current)(context Electric Cable)	1				1	↗											
F20 Distribute energy(context Energy Management System)	1								1			↗					
F21 define position(s : GPS Signal, pos : Position)(context Positioning system)	1								1					↗			
F31 takeOff(context Propulsion system)	1								1						↗		
F32 start Rotors(context Propulsion system)	1								1						↗		
F41 Take UAV control(context Remote Contol Station)	1								1							↗	

Benefits of models for *System Architecture Definition*

Eases synchronization and consistency of the different architectural views

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- **Centralized definition**
  - Automatic propagation of changes in name and interface
  - Automatic alignment of occurrences of same definition (reference)

- **Availability of types and links between model elements**
  - Ability to check connection of functions (output to input)
  - Ability to check physical links (port to port)
  - Ability to check allocations of functions to system elements (availability of physical links to carry functional flows)
  - Ability to check completeness (queries about orphan elements)

Return from industrial experience

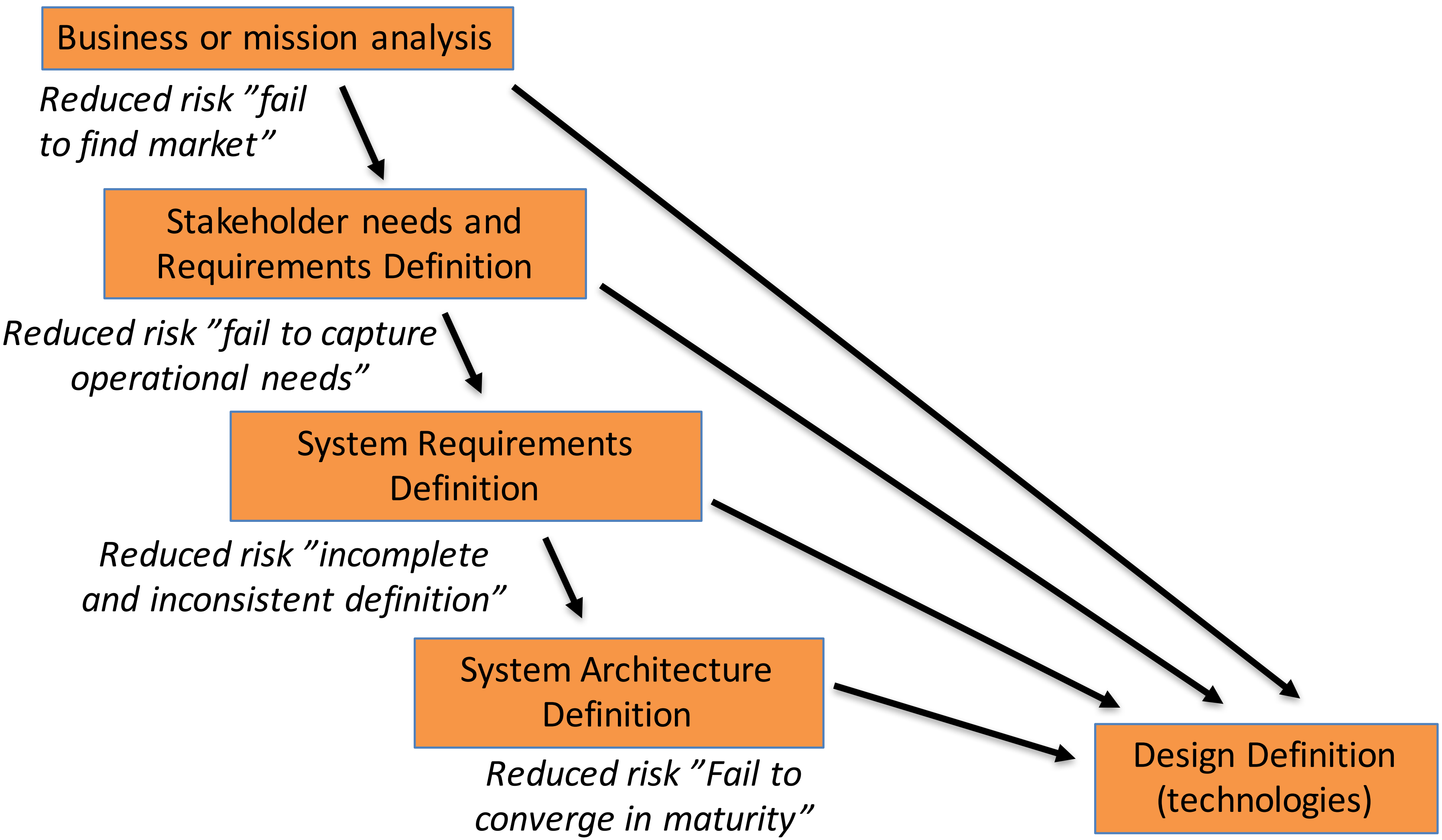
- **Context / modelling opportunity**
  - Avionic solution with a lot of MS Visio drawings to maintain
  - Investigation on models to ease the building of a consistent architecture

- **Results**
  - Block diagrams used to formalize solution topology and allocation of functional data on topology
  - Simplified update of topology and change propagation
  - Simplified identification of functional flows through topology
  - Ensured consistency between different contractual documents

Formal modelling helped System Engineers building consistent views of their system architecture (by construction and automated verification)

Summary

SE processes to mitigate risks



Formal models can support a lot of systems engineering definition activities

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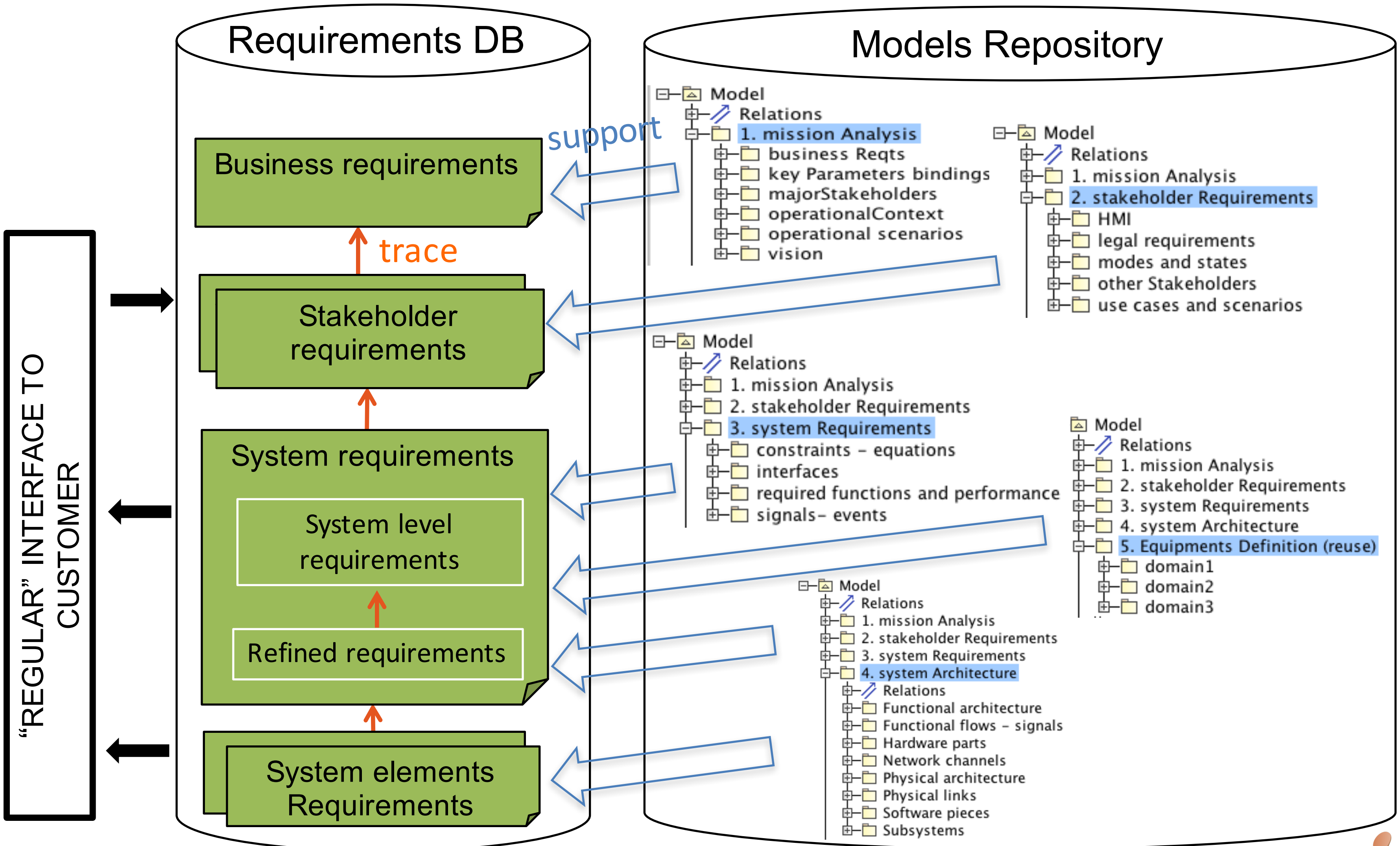

Formal models can support analysis and verification of System Definition

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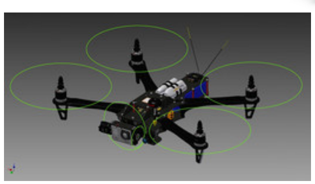
Advanced computing,
Space design exploration

Security analysis

Thermal analysis

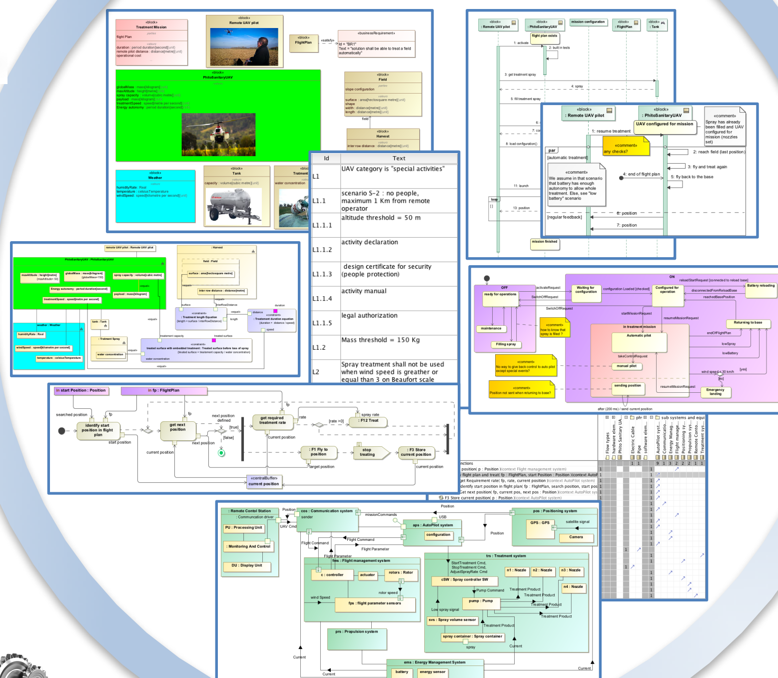
Acoustic analysis

Mechanical aspect,
sizing constraints

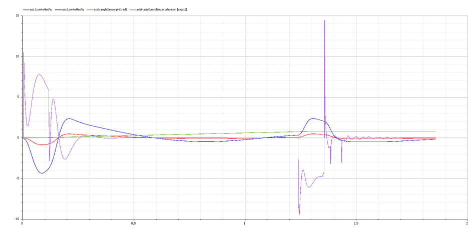


…

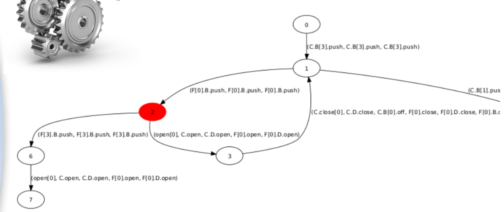
Business, stakeholder
and system requirements



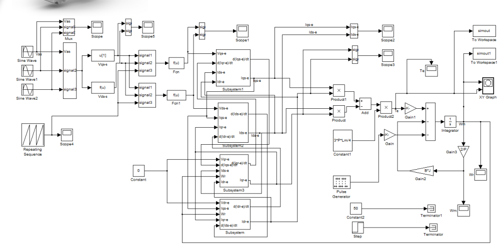
Multi physical analysis
and simulation



Safety analysis



Control command
algorithms



…

No need to formalize everything

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1. Focus on high engineering costs
2. Align team on process (vocabulary, standard…)
3. Choose modeling views that will improve engineering
4. Choose / adapt tool to support model and views
5. Create model, raise questions/issues and review it
6. Measure benefits and coach future model owner
7. Iterate on new costs and new modeling/tool opportunities

Part B

Some keys toward advanced MBSE

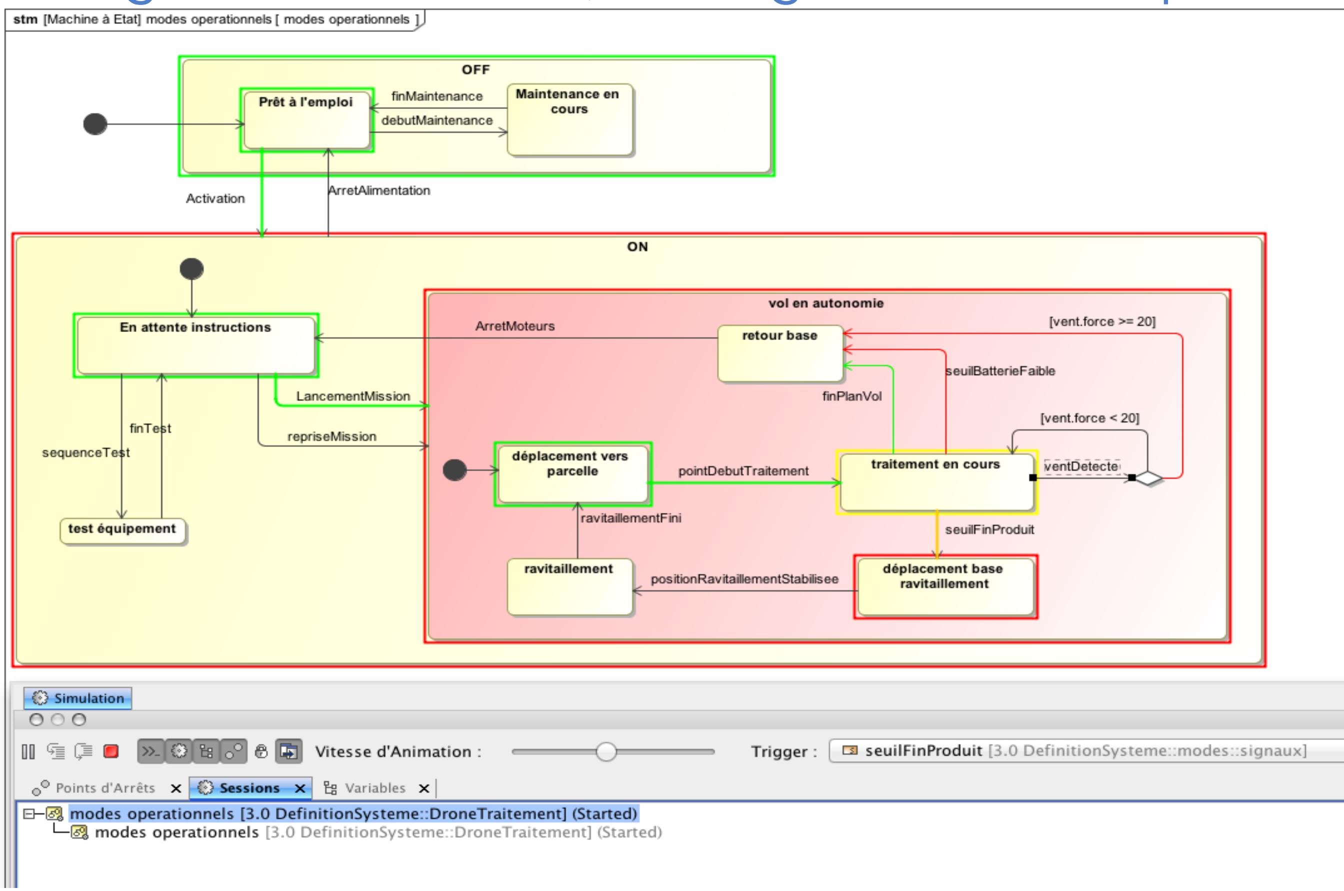
Understand MBSE potential and constraints

Benefits scale with modeling efforts(1)

- **Just want to illustrate concepts?**
  - Why spending efforts with a restricted notation?
  - Informal models are enough: Visio /PowerPoint fit
- **Want to clarify concepts or requirements?**
  - Need precise and shared (standard) notation
  - Can still use Visio or PowerPoint but with detailed legend: might reinvent existing languages (lot of efforts, notation constraint) !
- **Want to propagate changes in collaborative work?**
  - Need to use views synchronized on a shared model: have to learn both modeling notation and associated tool
  - Visio and PowerPoint are not your friends..

Benefits scale with modeling efforts(2)

- **Want to perform analysis?**
  - Need to get formal models (unambiguous notation, precise sem
  - Can thro

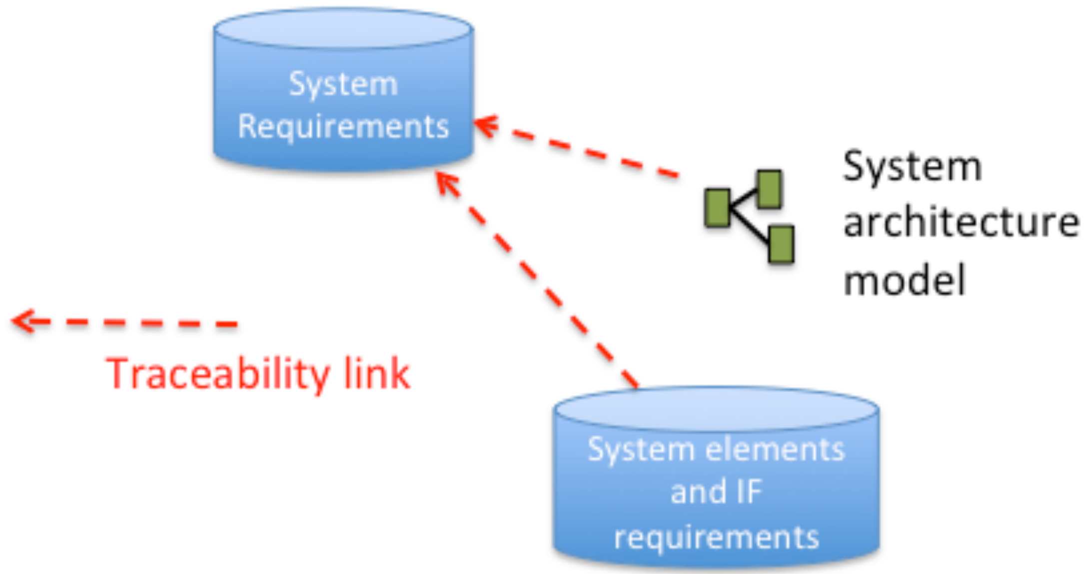


- **Want**
  - Nee ...ion)
  - Nee

- **Want**
  - Nee ... time
    inve

Benefits scale with modeling efforts(3)

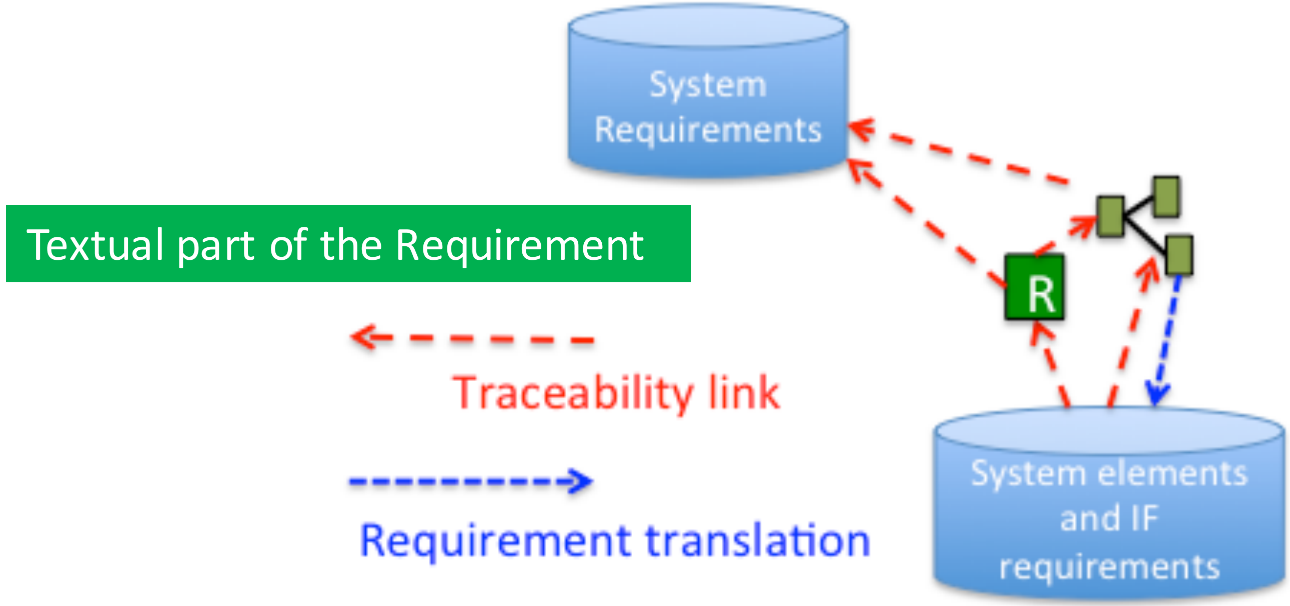
- **Want to consider models on long term?**
  - Models become engineering artefacts: have to be managed in configuration and traced to requirements



  - Are you ready to maintain models on long term?
  - Are you ready to maintain traceability on long term?

Benefits scale with modeling efforts(4)

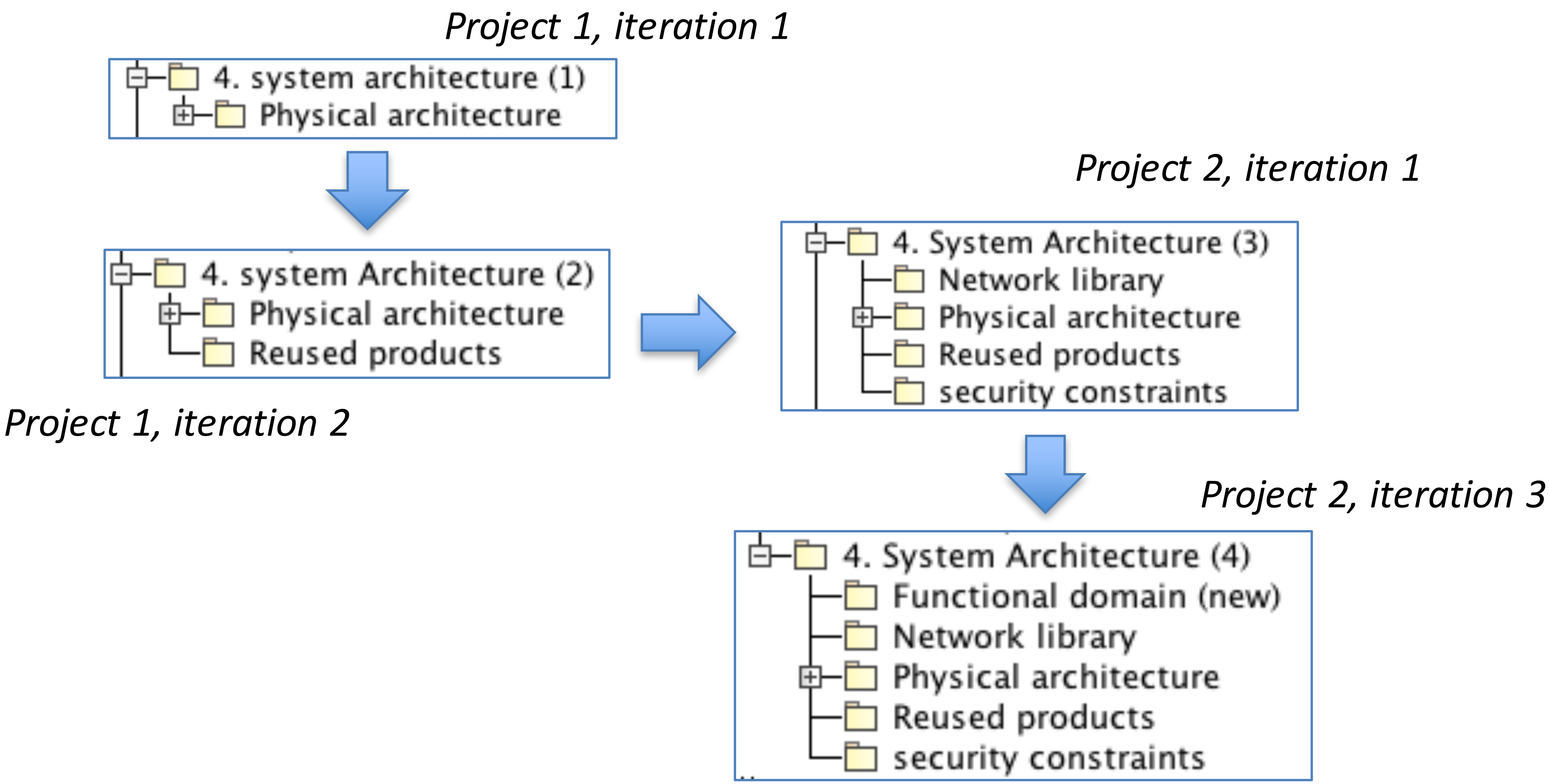
- **Want to generate specification from models?**
  - Models shall contain all required specification information (including textual part if it can not be formalized graphically)



  - Models shall be the master repository or fully synchronized with it
  - Are you organized to update model instead of document?

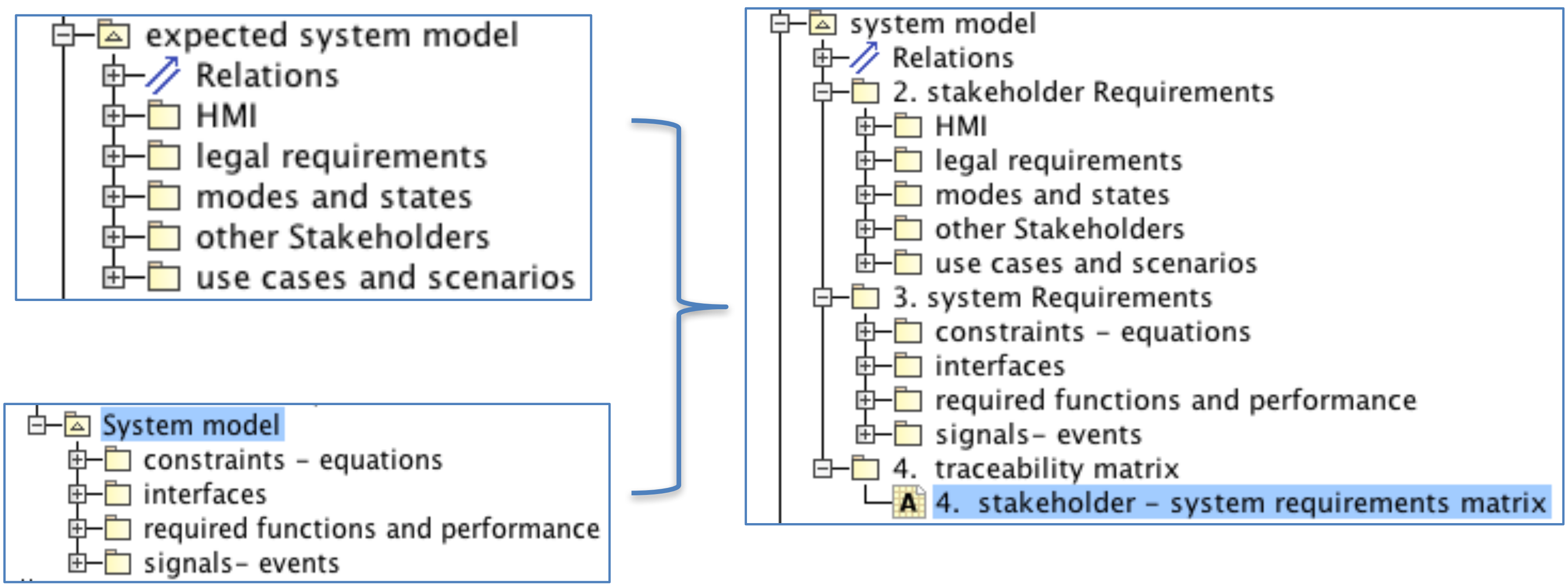
Incremental MBSE deployment

- **Example**

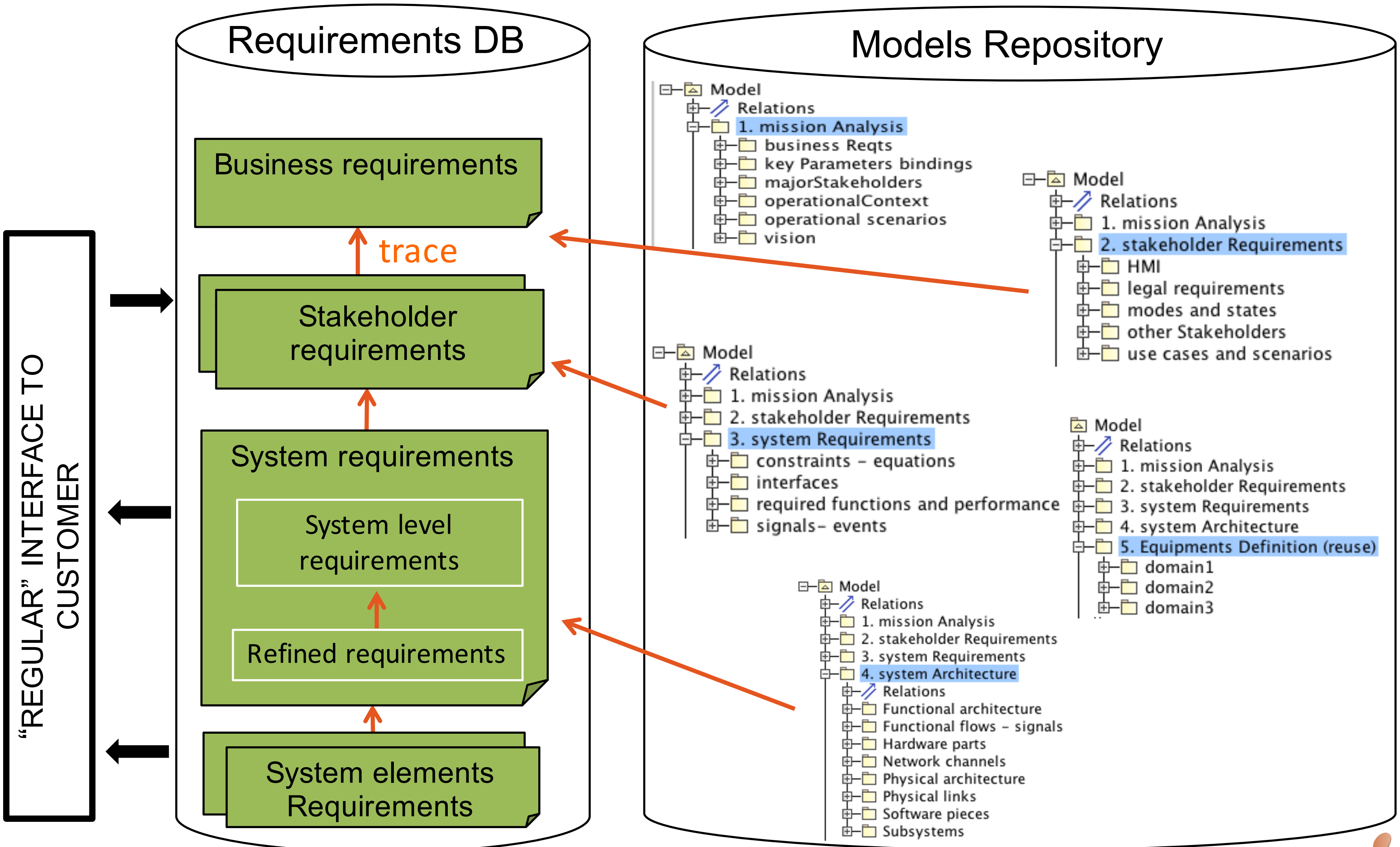

Project 1, iteration 1
4. system architecture (1)
Physical architecture
4. system Architecture (2)
Physical architecture
Reused products
Project 1, iteration 2
Project 2, iteration 1
4. System Architecture (3)
Network library
Physical architecture
Reused products
security constraints
Project 2, iteration 3
4. System Architecture (4)
Functional domain (new)
Network library
Physical architecture
Reused products
security constraints

Connect different models

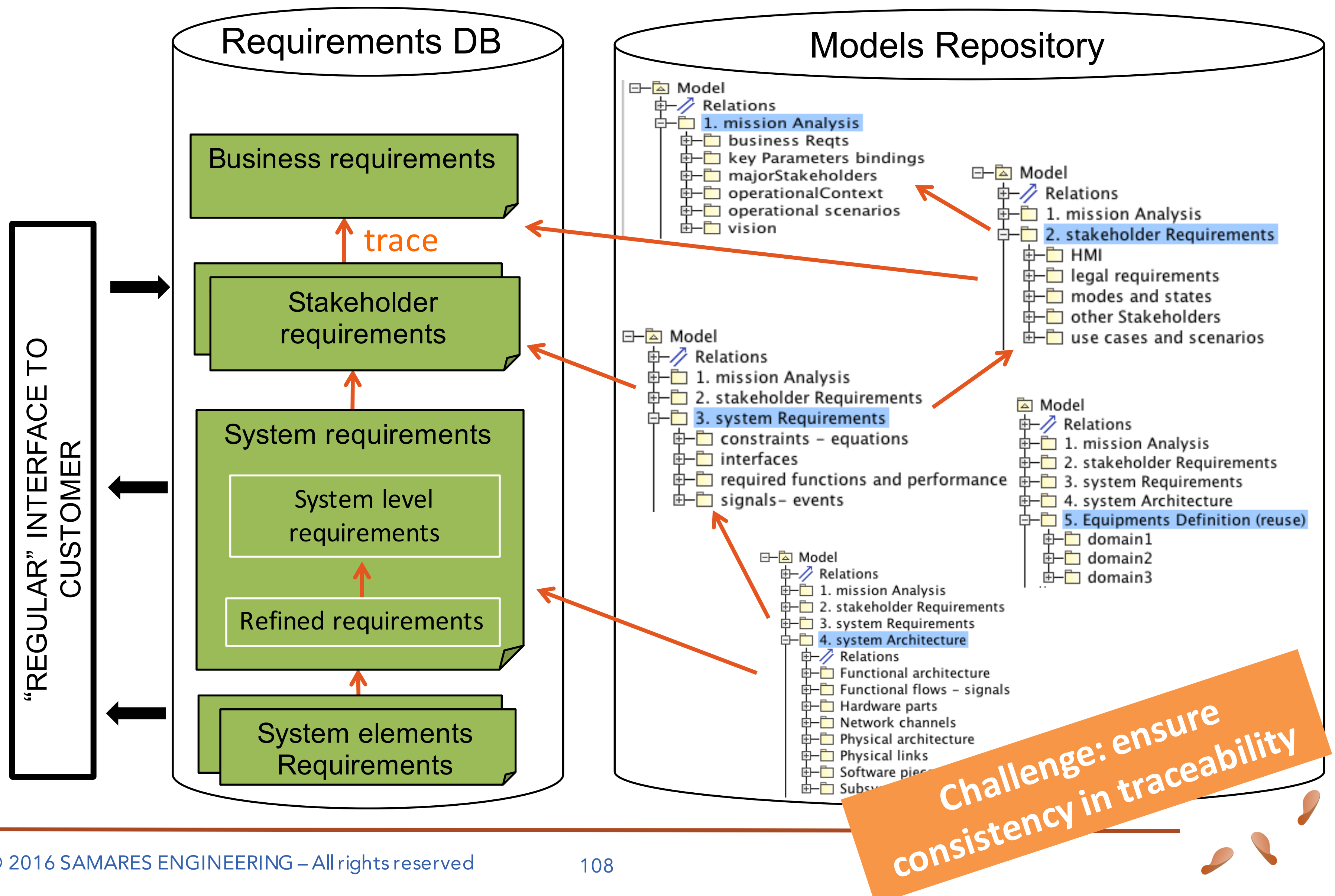
- **Example with two different engineering levels**
  - Added value is in refinement support and traceability



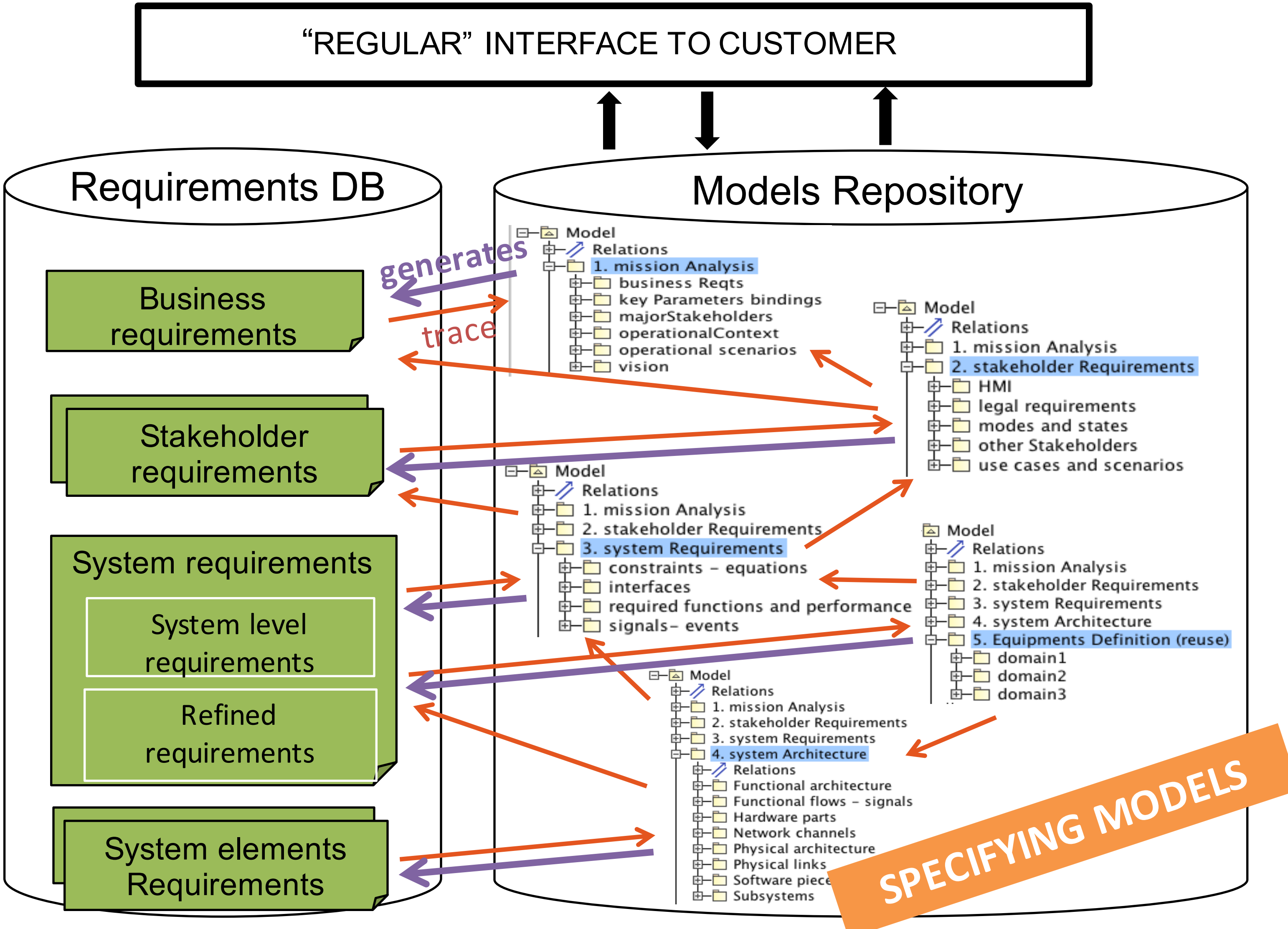
Long term MBSE - models traced to requirements



Advanced MBSE - models traced to requirements and between each other



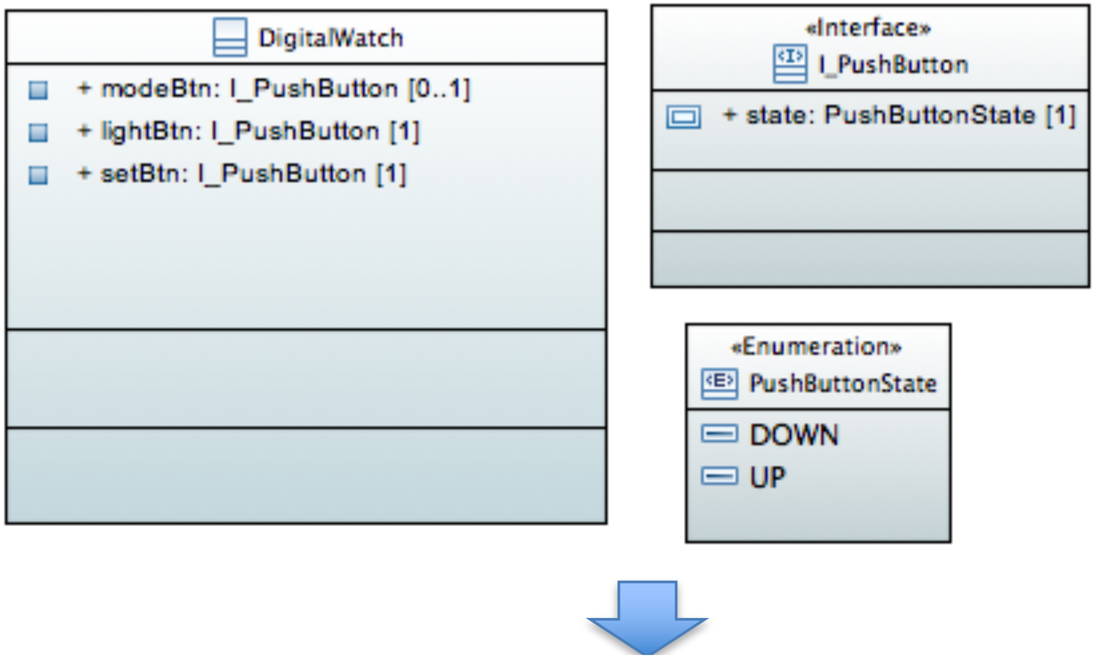
Full MBSE – traceability through models



Remaining challenges (research)

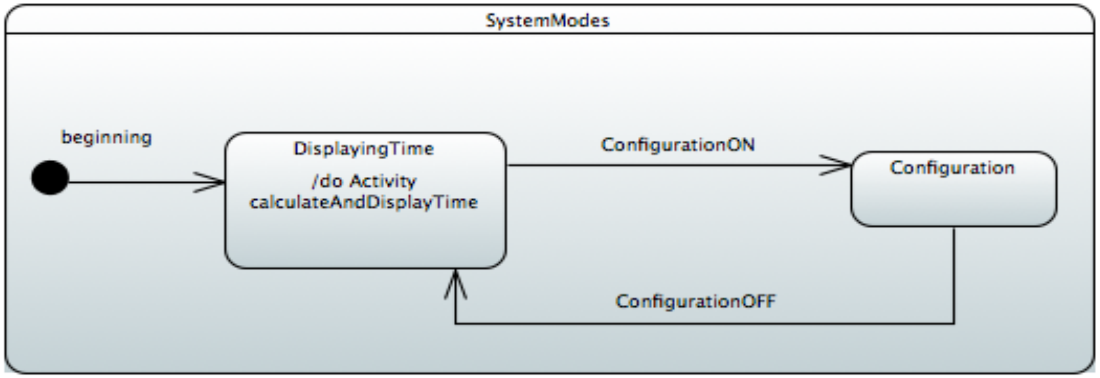
- Traceability between models from different languages
- Traceability between models from different companies
- Configuration management of models
- Identification of requirements within models
  - Identify model elements as requirements
- Identification of traceability links within models
- Generation of readable requirements from models

Identify requirements from models (1)



Req ID	Req Text
Model_modelBtn	An item of type “DigitalWatch” shall have one optional “modelBtn” port(s) of the “I_PushButton” type
Model_setBtn	An item of type “DigitalWatch” shall have one and only one “setBtn” port(s) of the “I_PushButton” type
Model_lightBtn	An item of type “DigitalWatch” shall have one and only one “lightBtn” port(s) of the “I_PushButton” type

Identify requirements from models (2)



Model_Transition0	If the "SystemModes" state machine is in "DisplayTime" state, it shall exit this state and enter the "Configuration" State on reception of event "ConfigurationON"
Model_Transition1	If the "SystemModes" state machine is in "Configuration" state, it can exit this state and enter the "DisplayTime " State on reception of event "ConfigurationOFF"
Model_DisplayTime	The "SystemModes" state machine defines the "DisplayTime" sub-state(s).
Model_Configuration	The "SystemModes" state machine defines the "Configuration" sub-state(s).
Model_displayTime	By invocation, an item of type "calculateAndDisplayTime" shall behave as specified by its "displayTime" activity definition
Model_beginning	The "SystemModes" state machine starts in the "DisplayTime" (sub) state

Questions / discussion

Thank you for your attention

- **AFIS**
  - New MBSE working groups about to start: still time to join
  - Contacts
    - Raphael.faudou@samares-engineering.com
    - marco.ferrogalini@rail.bombardier.com (head of MBSE committee)