Model-Based Systems Engineering Approach to Managing Mass Margin

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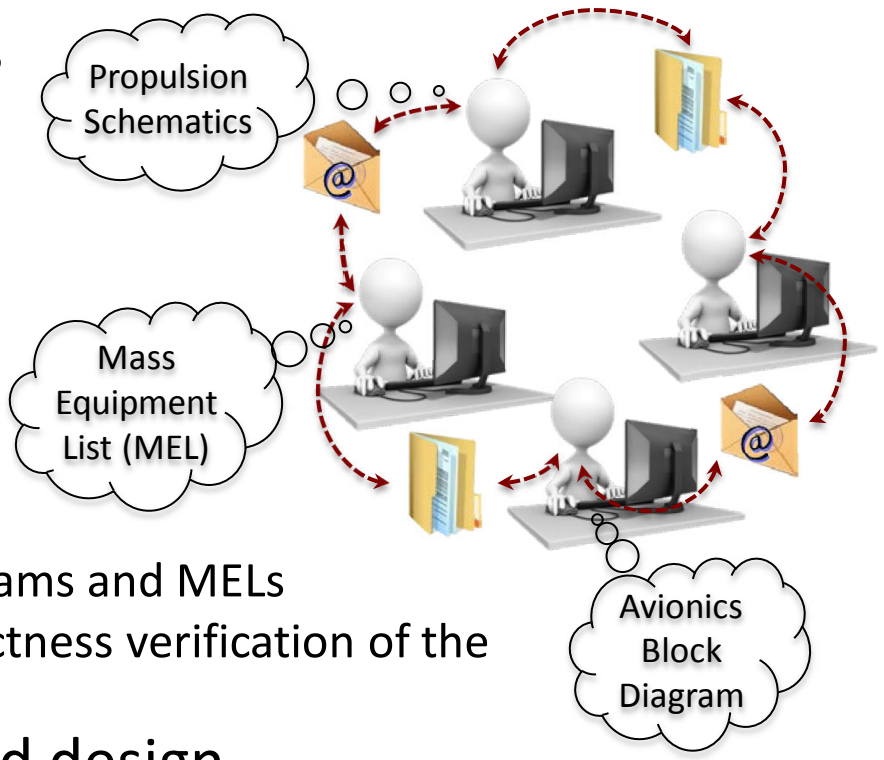
October 19, 2012

- SECESA 2012 -

5th International Workshop on Systems & Concurrent Engineering for Space Applications

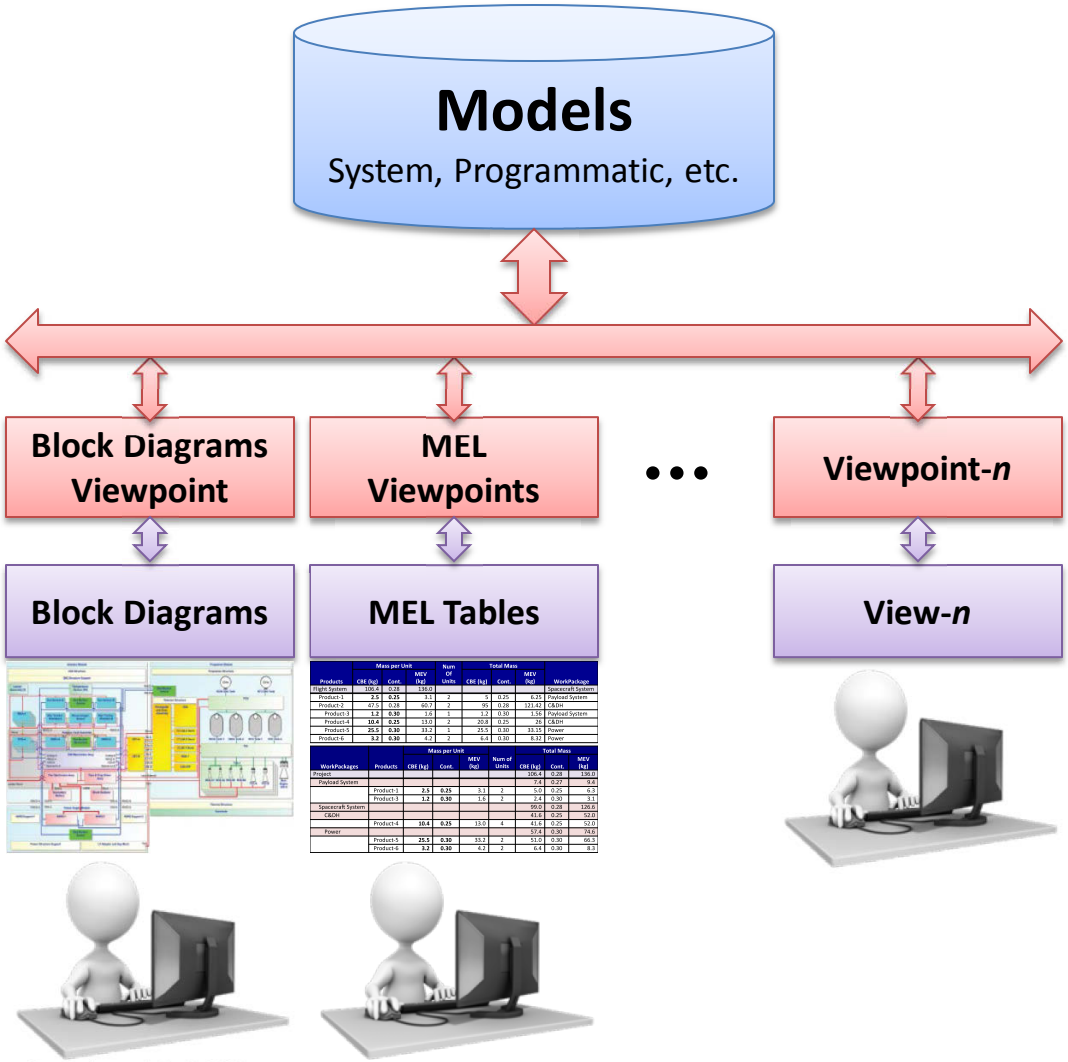
Multiple Sources of Truth

- Consistency and correctness
  - Multiple mass equipment lists (MELs)
    - Different versions of MEL spreadsheets owned by the systems and subsystems engineers
  - Implicit block diagram and MEL relationship
    - Manual creation of the diagrams and MELs
    - Visual consistency and correctness verification of the diagrams and MEL
- Iterating the architecture and design
  - Manual updating MEL and block diagrams *consistently* and *correctly*



Model-Based Systems Engineering Framework

Model as the Single-Source-of-Truth



Consistency

- Enforced by having a single-source-of-truth, the models

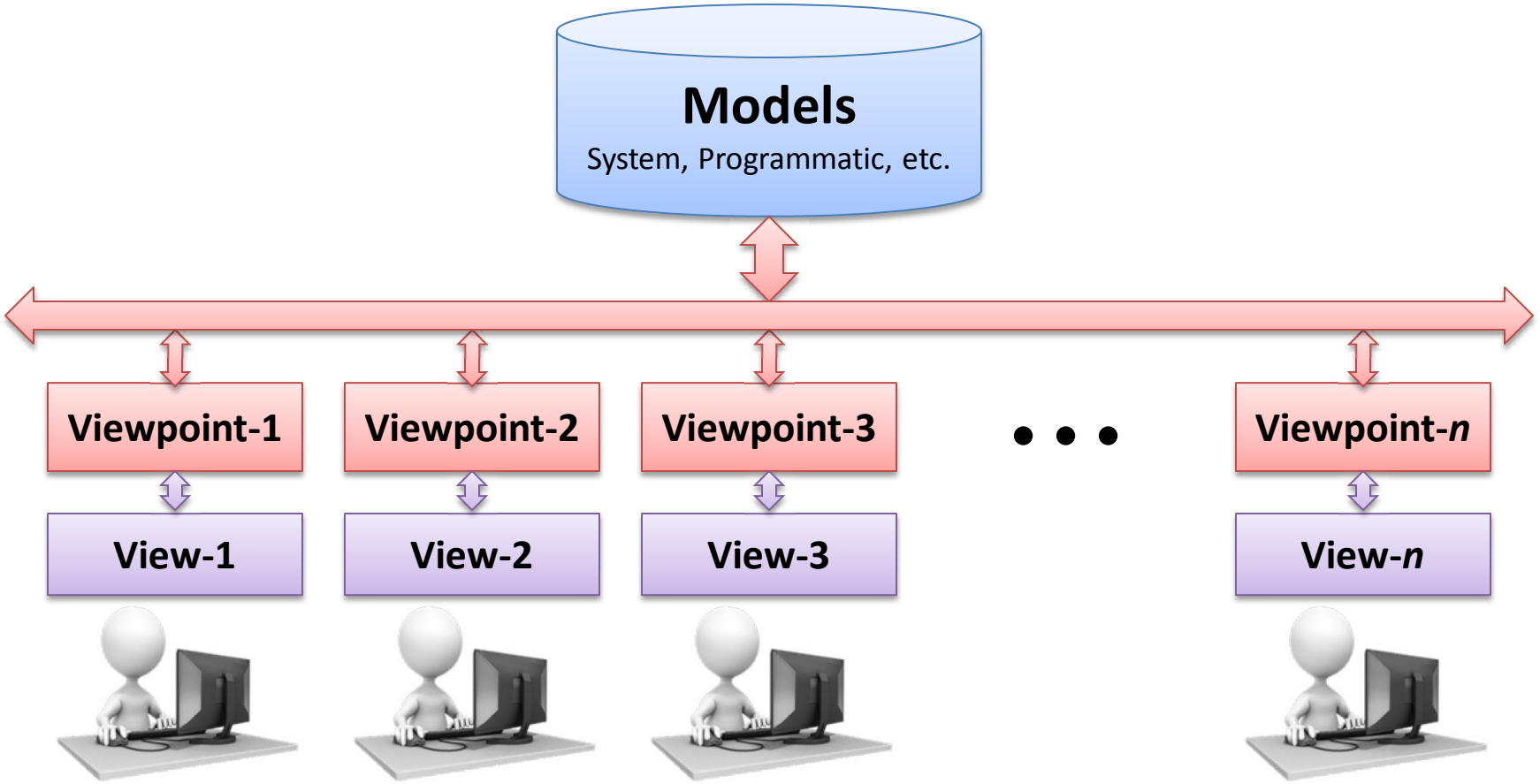
Correctness

- Enforced through verification checks and reviews from various viewpoint of the Model

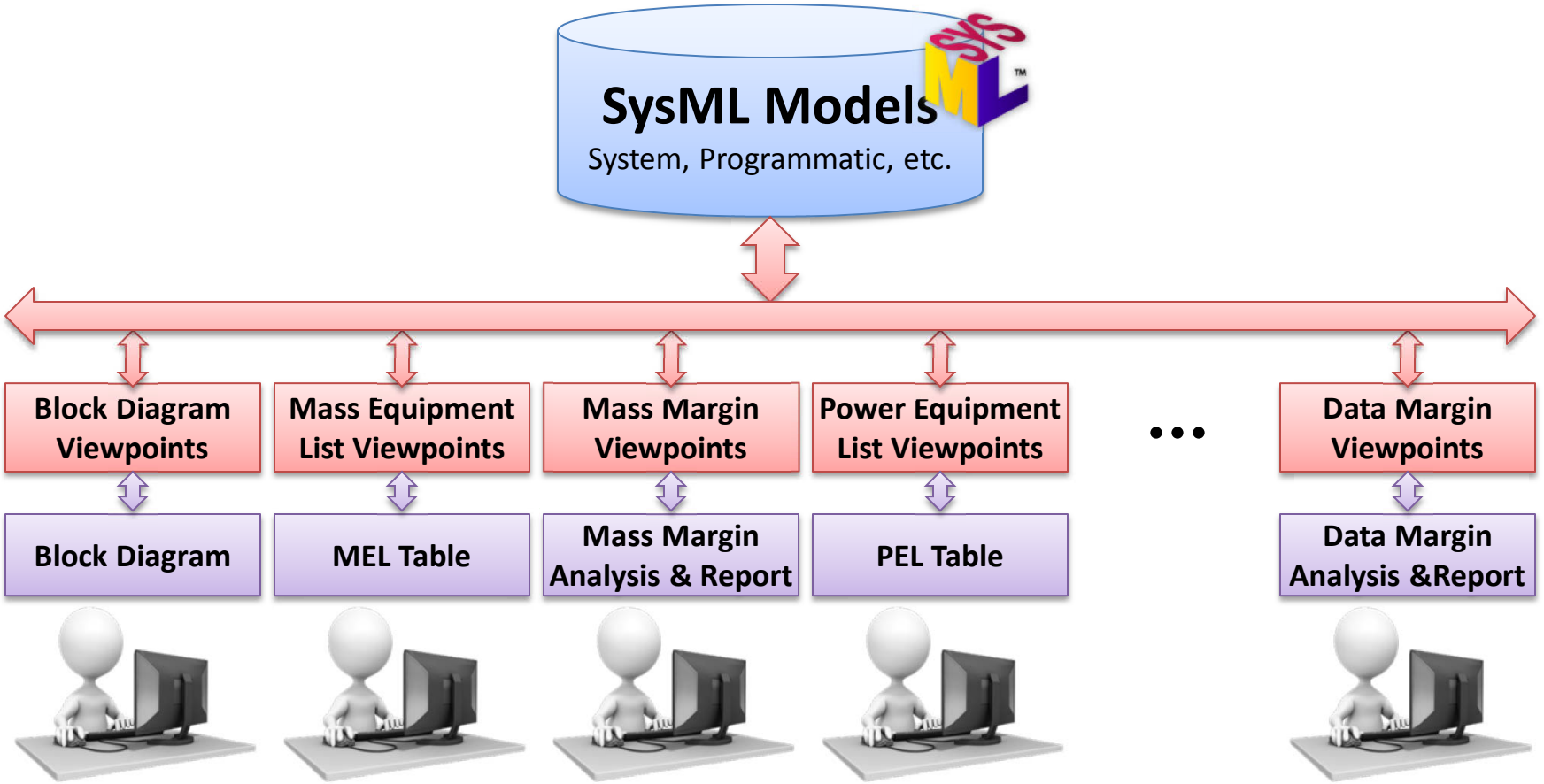
Model-Based Systems Engineering Approach to Managing Mass Margin

EHM MODEL-BASED SYSTEMS ENGINEERING FRAMEWORK

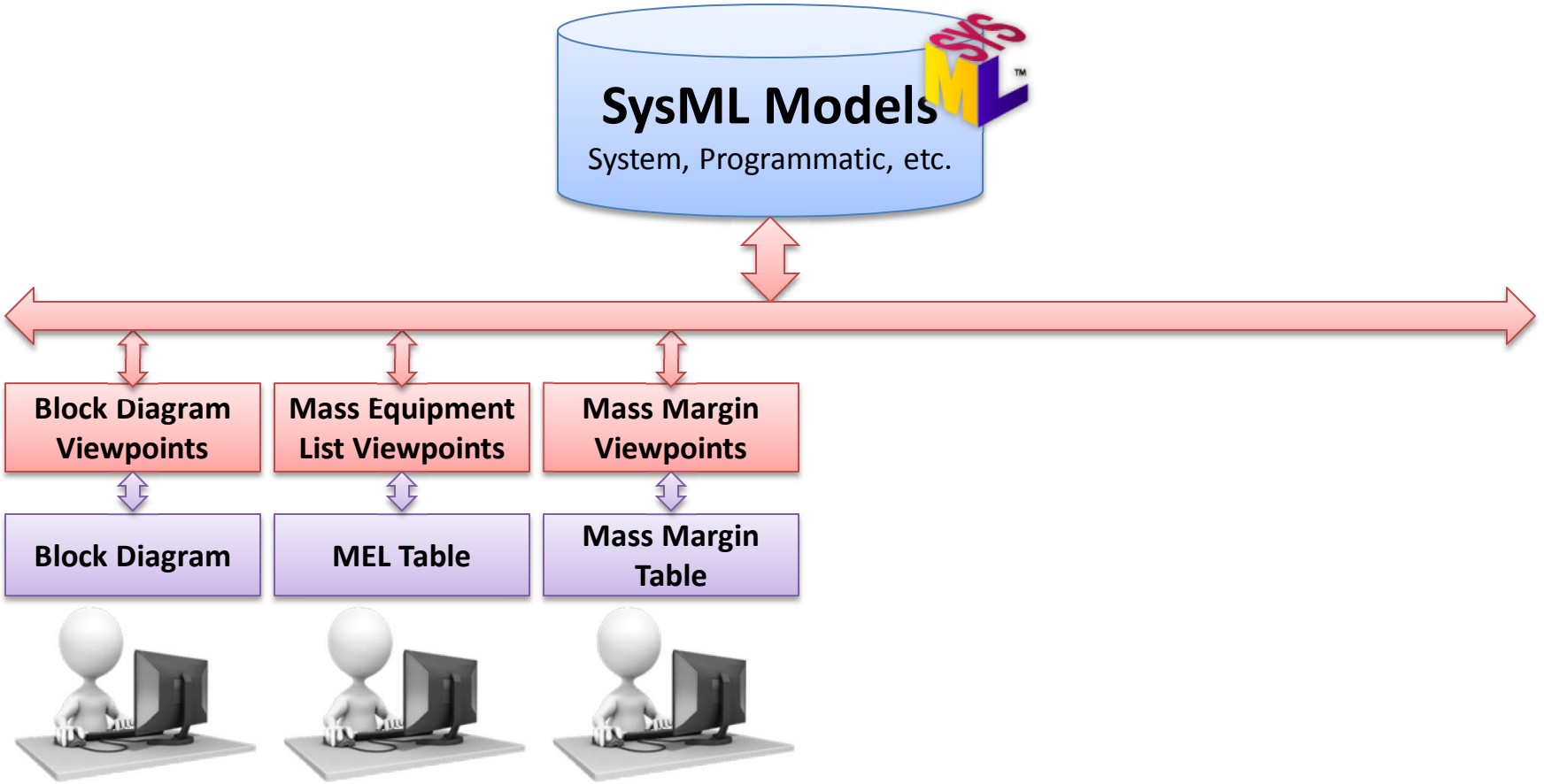
Viewpoint-Based Framework Concept



EHM Viewpoint-Based Framework



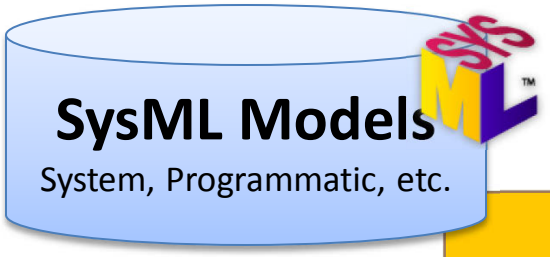
EHM Viewpoint-Based Framework

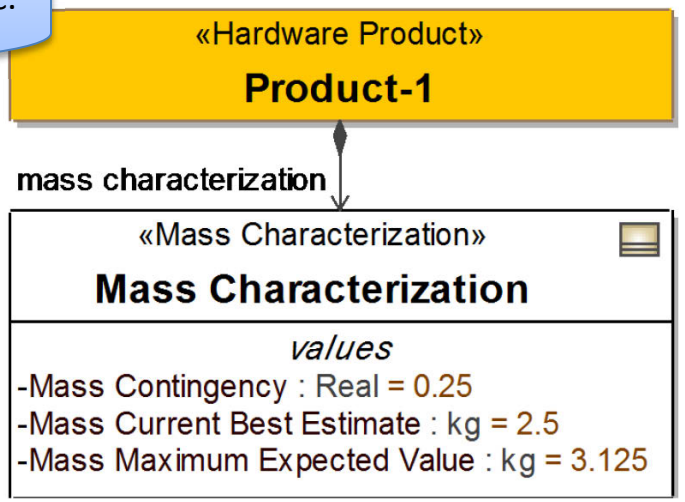


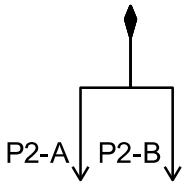
Model-Based Systems Engineering Approach to Managing Mass Margin

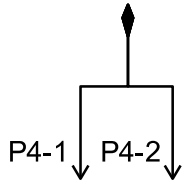
MODELS FOR MELS AND MASS MARGIN ANALYSIS

System Structural Model









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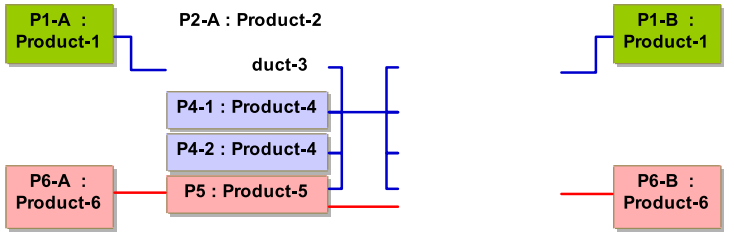
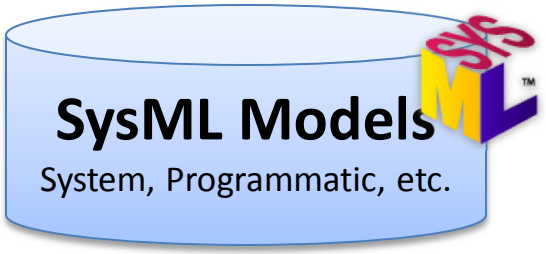
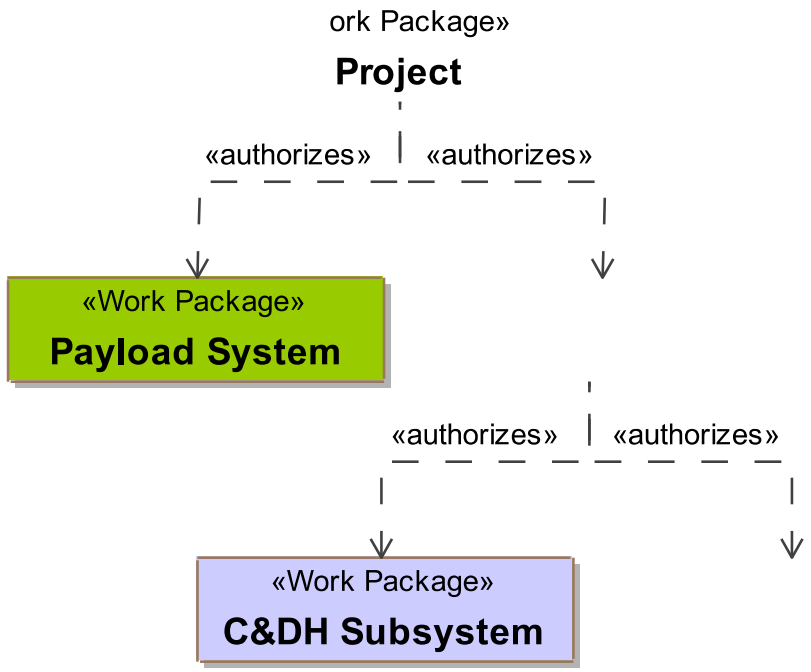


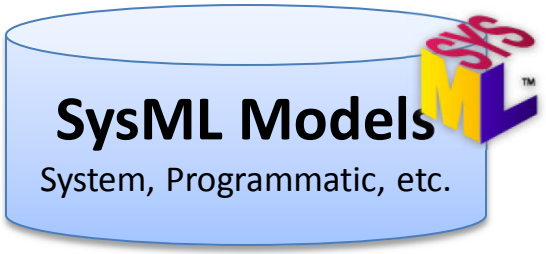
Work Breakdown Structure Model

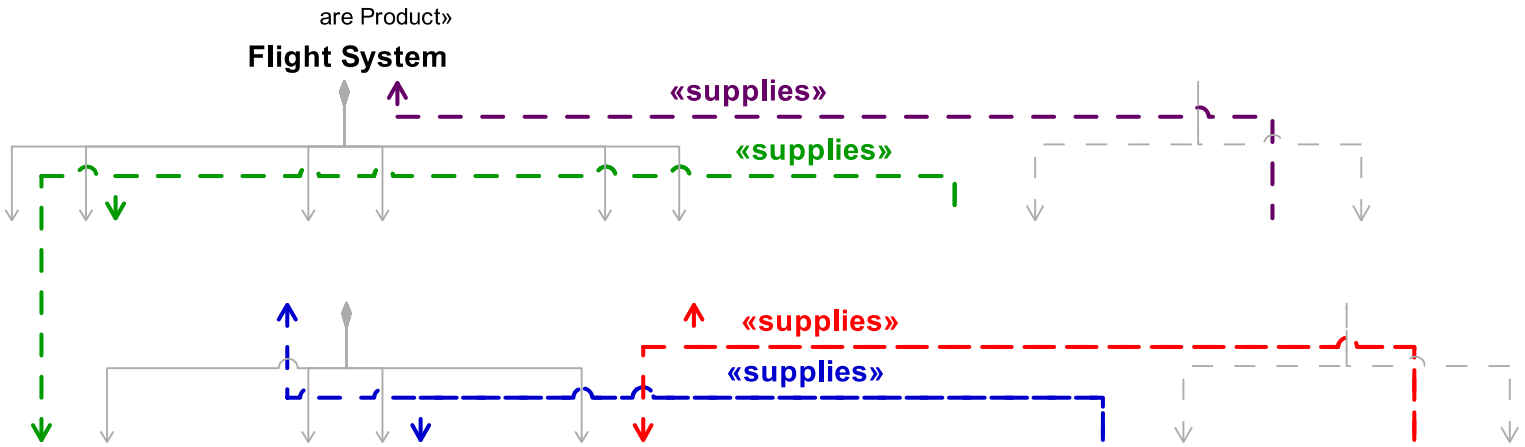




Models for MELs and Mass Margins

Work Package Supplies Model



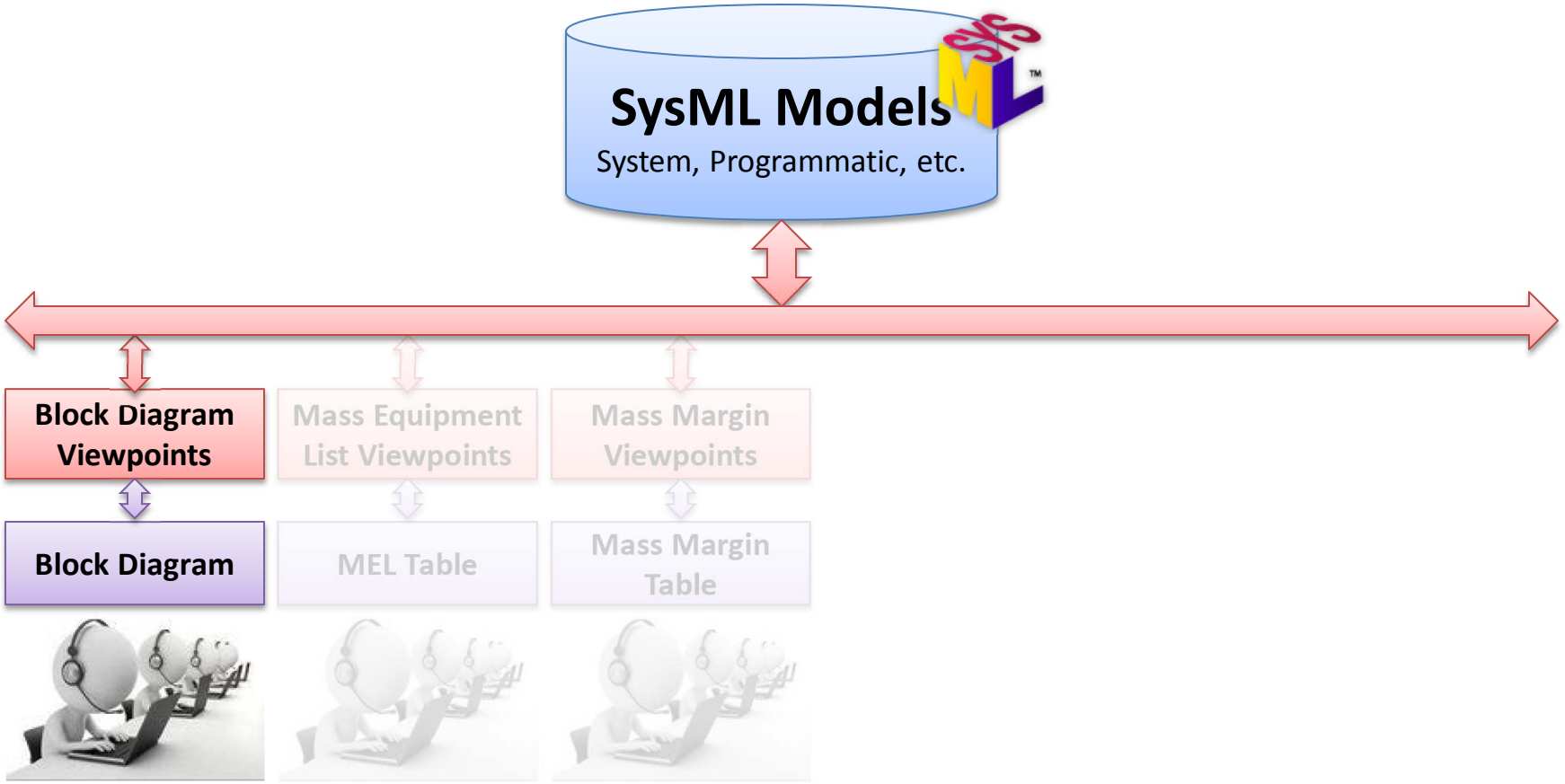


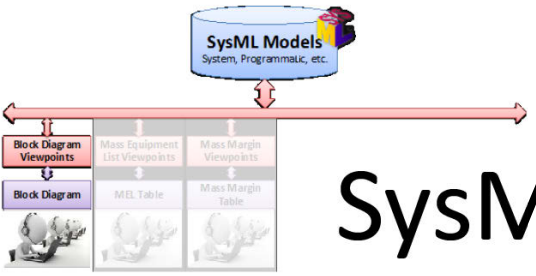
Model-Based Systems Engineering Approach to Managing Mass Margin

EHM PROJECT VIEWS AND VIEWPOINTS

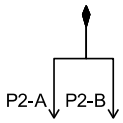
EHM Project Views and Viewpoints

Block Diagram Views





SysML IBDs as Block Diagram



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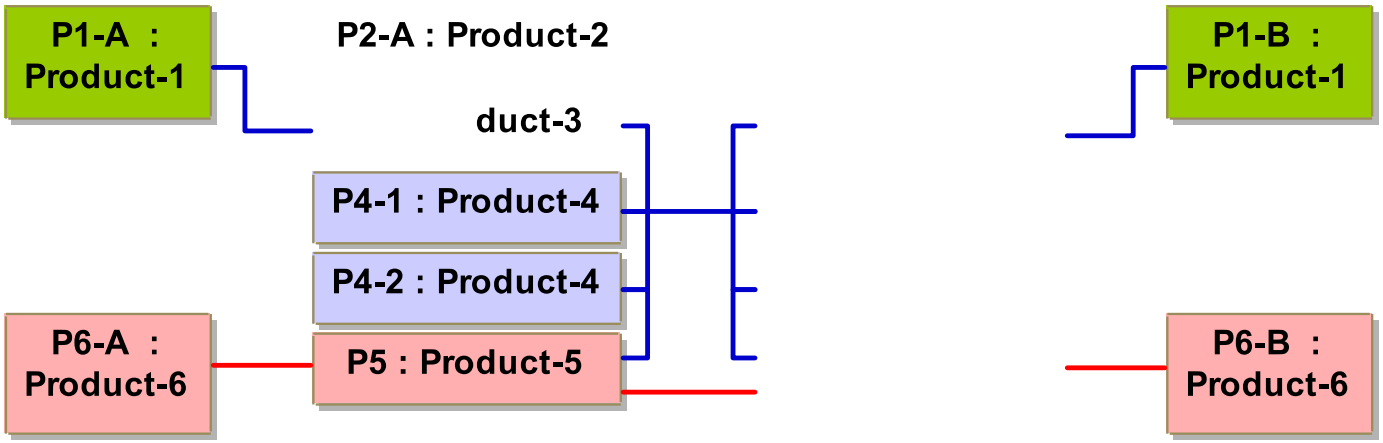
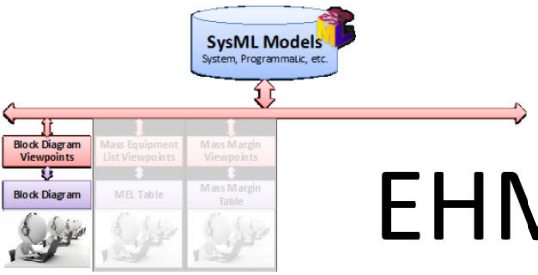
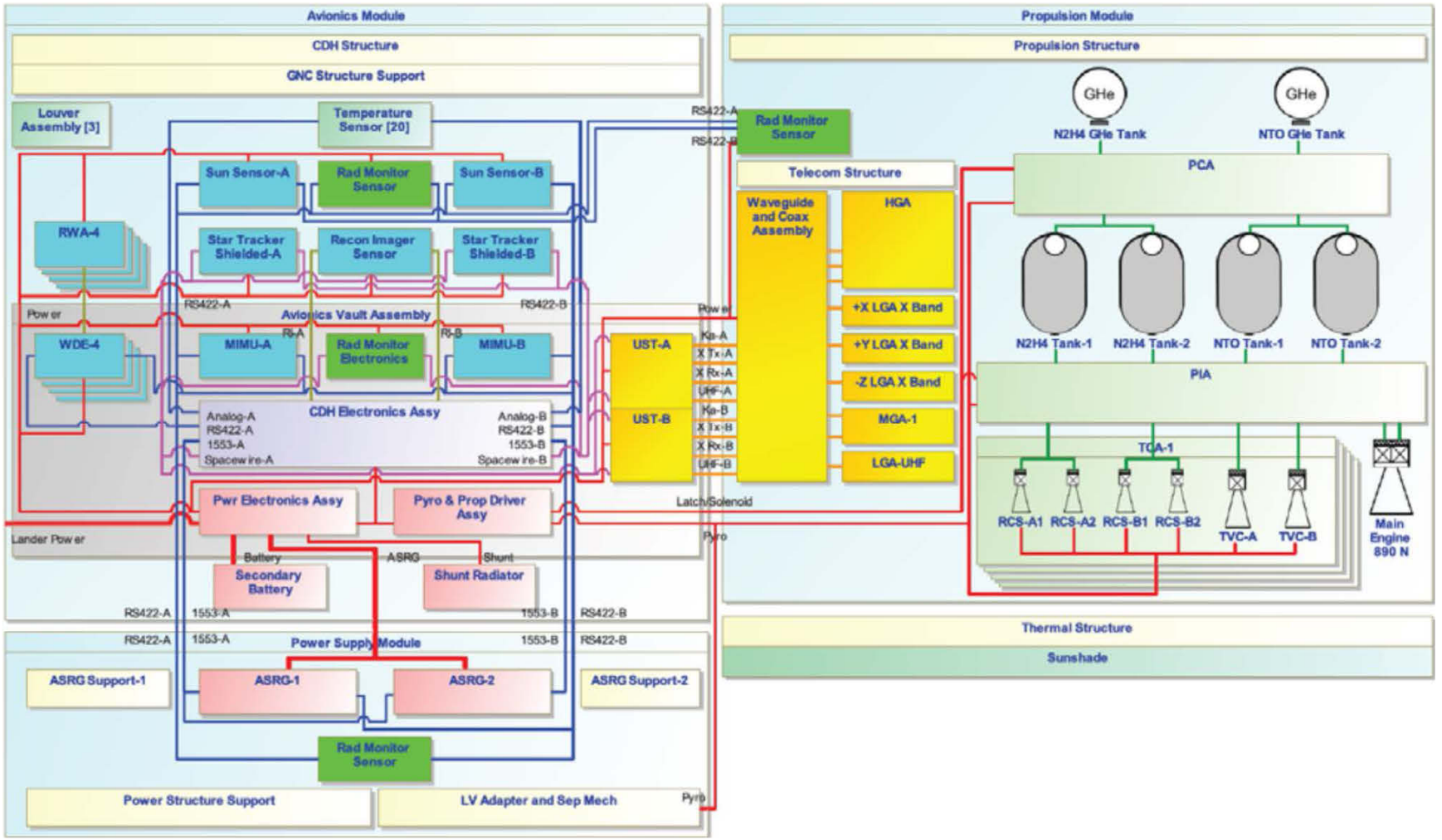


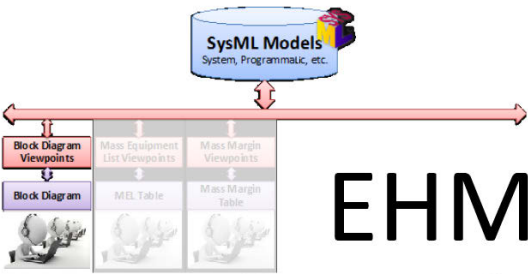


Block Diagram Views

EHM Carrier Block Diagram



Europa Study Team. Europa study 2012 report. JPL D-71990, NASA, May 1 2012.

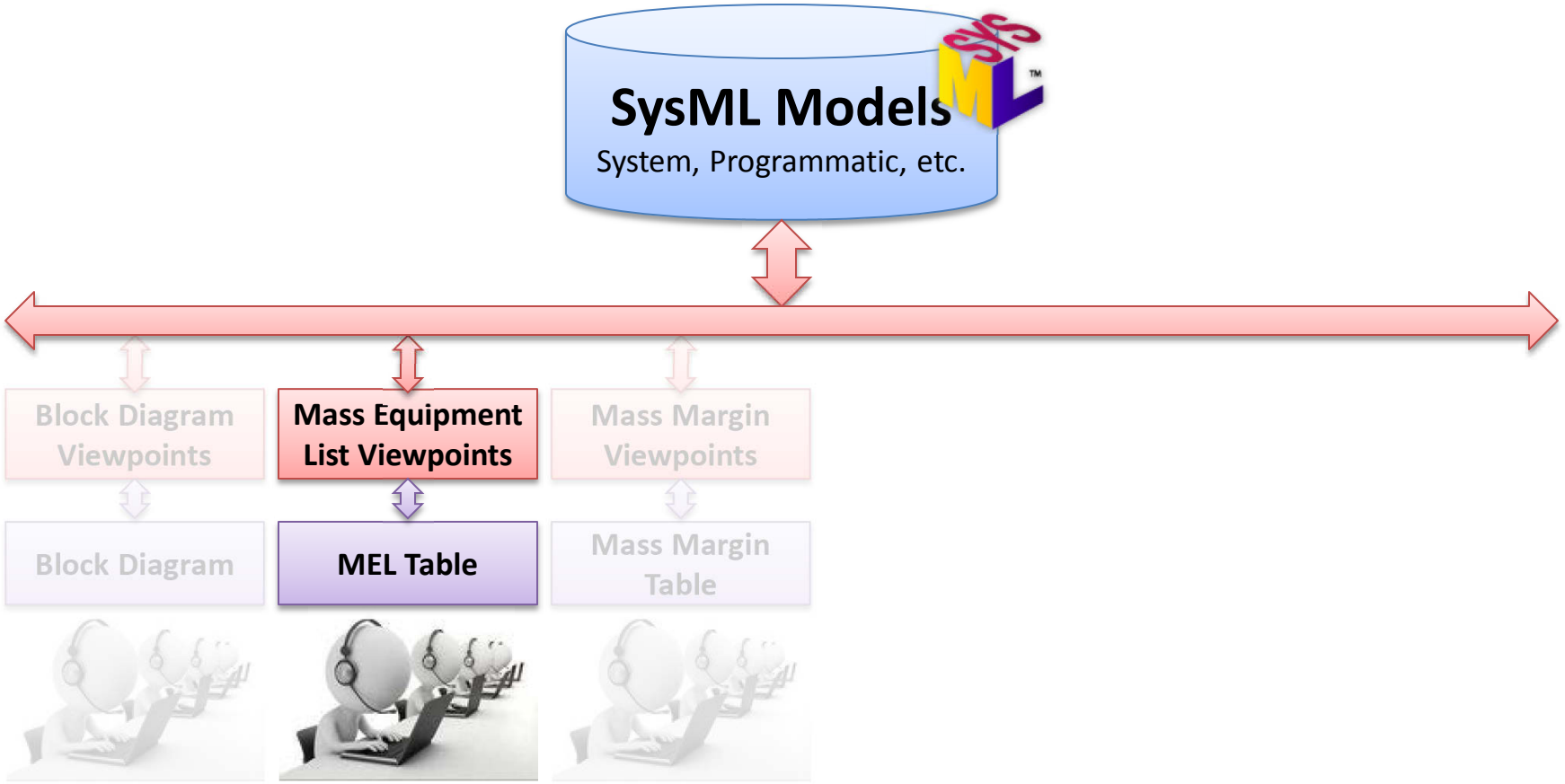


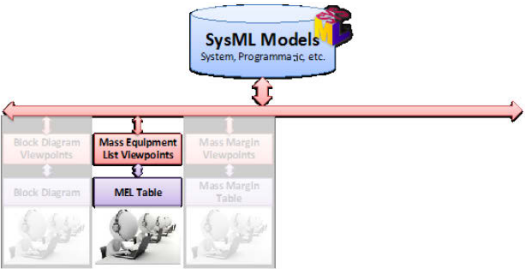
Block Diagram Views

EHM Carrier Prop Schematics

Europa Study Team. Europa study 2012 report. JPL D-71990, NASA, May 1 2012.

Mass Equipment List (MEL) Views

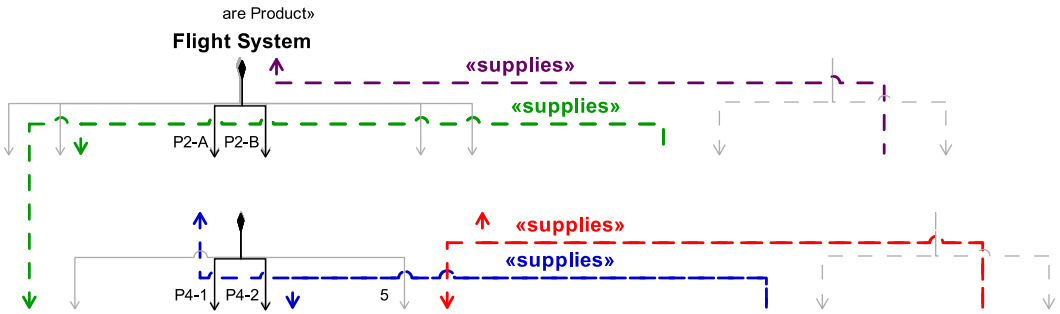


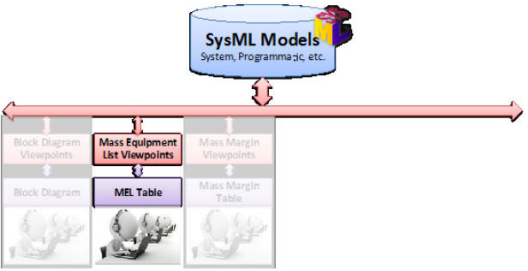


Mass Equipment List (MEL) Views

Deployment

Products	Mass per Unit			Num Of Units	Total Mass			WorkPackage
	CBE (kg)	Cont.	MEV (kg)		CBE (kg)	Cont.	MEV (kg)	
Flight System	106.4	0.28	136.0					Spacecraft System
Product-1	**2.5**	**0.25**	3.1	2	5	0.25	6.25	Payload System
Product-2	47.5	0.28	60.7	2	95	0.28	121.42	C&DH
Product-3	**1.2**	**0.30**	1.6	1	1.2	0.30	1.56	Payload System
Product-4	**10.4**	**0.25**	13.0	2	20.8	0.25	26	C&DH
Product-5	**25.5**	**0.30**	33.2	1	25.5	0.30	33.15	Power
Product-6	**3.2**	**0.30**	4.2	2	6.4	0.30	8.32	Power

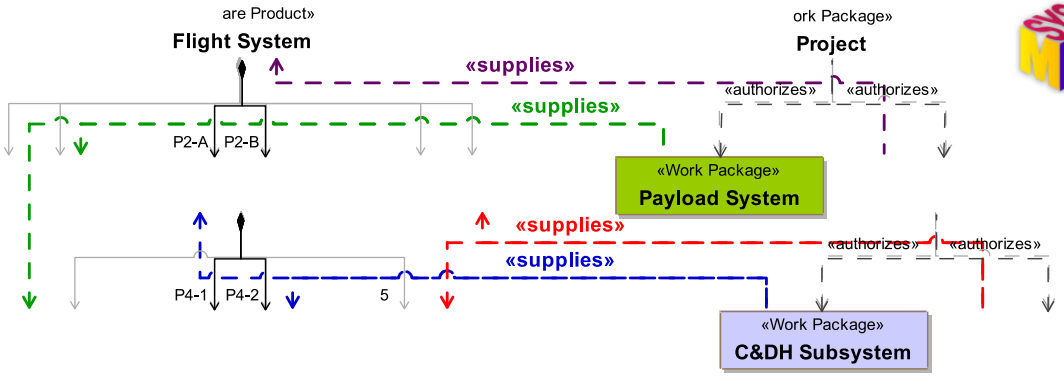




Mass Equipment List (MEL) Views

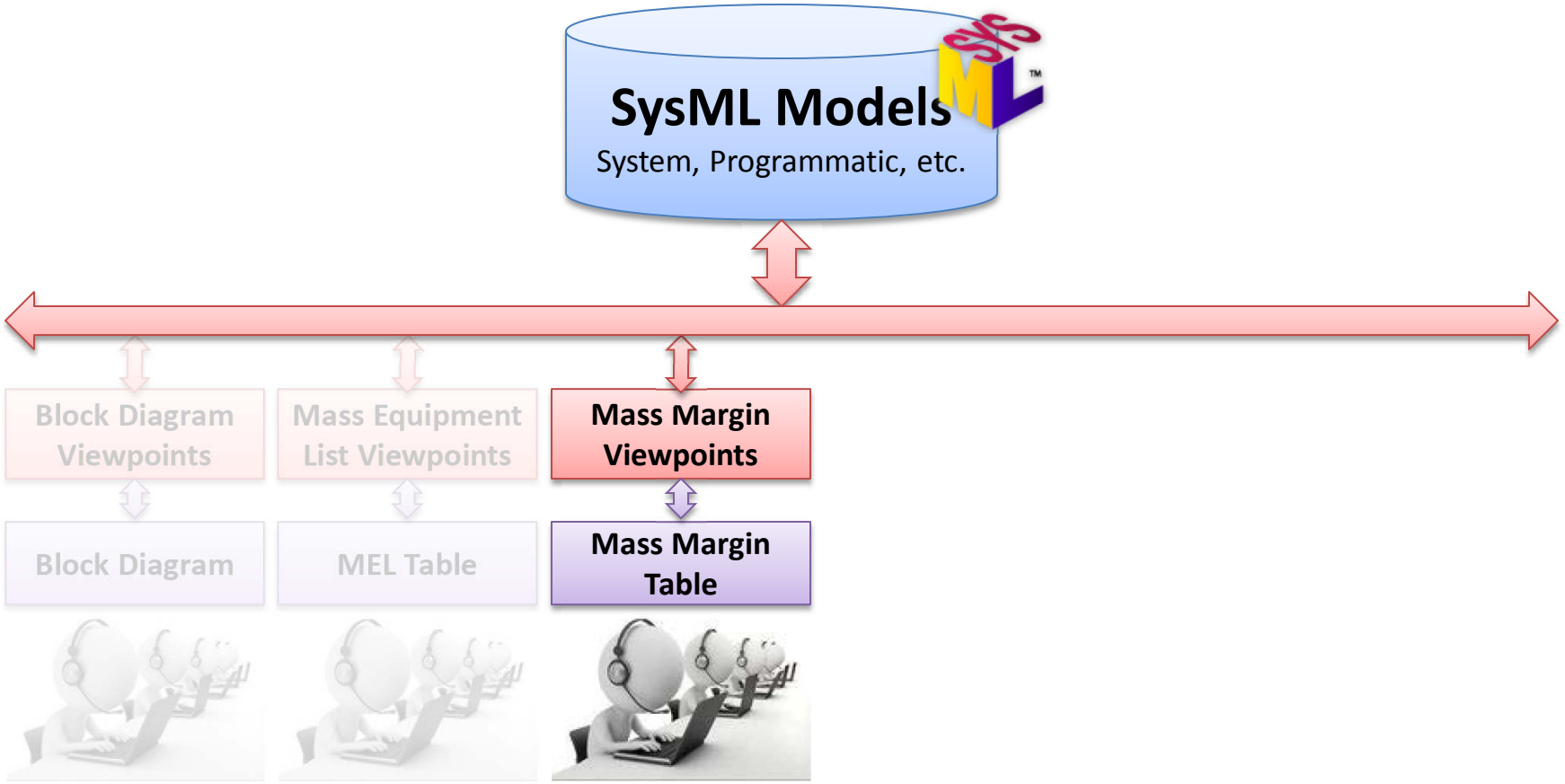
Bill of Materials

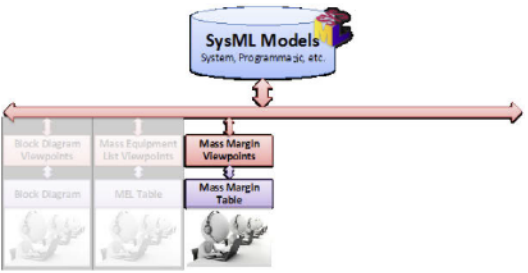
WorkPackages	Products	Mass per Unit			Num of Units	Total Mass		
		CBE (kg)	Cont.	MEV (kg)		CBE (kg)	Cont.	MEV (kg)
Project						106.4	0.28	136.0
Payload System						7.4	0.27	9.4
	Product-1	**2.5**	**0.25**	3.1	2	5.0	0.25	6.3
	Product-3	**1.2**	**0.30**	1.6	2	2.4	0.30	3.1
Spacecraft System						99.0	0.28	126.6
C&DH						41.6	0.25	52.0
	Product-4	**10.4**	**0.25**	13.0	4	41.6	0.25	52.0
Power						57.4	0.30	74.6
	Product-5	**25.5**	**0.30**	33.2	2	51.0	0.30	66.3
	Product-6	**3.2**	**0.30**	4.2	2	6.4	0.30	8.3



EHM Project Views and Viewpoints

Mass Margin View





Mass Margin View

Mass Margin Table

Europa Study Team. Europa study 2012 report. JPL D-71990, NASA, May 1 2012.

T. Bayer 24 Apr 2012	LAUNCH		
Flyby Model - Final Report Update			
	CBE	Cont.*	MEV
Ion & Neutral Mass Spectrometer	24	50%	36
Ice Penetrating Radar	33	50%	50
ShortWave IR Spectrometer	21	50%	31
Topographical Imager	7	50%	11
Payload	85	50%	127
Power			

From MEL: Bill-of-Materials View

WorkPackages	Products	Mass per Unit CBE (kg)	Mass per Unit Cont.	Mass per Unit MEV (kg)	Num of Units	Total Mass CBE (kg)	Total Mass Cont.	Total Mass MEV (kg)
Project						106.4	0.28	136.0
Payload System						7.4	0.27	9.4
	Product-1	**2.5**	**0.25**	3.1	2	5.0	0.25	6.3
	Product-3	**1.2**	**0.30**	1.6	2	2.4	0.30	3.1
Spacecraft System						99.0	0.28	126.6
C&DH						41.6	0.25	52.0
	Product-4	**10.4**	**0.25**	13.0	4	41.6	0.25	52.0
Power						57.4	0.30	74.6
	Product-5	**25.5**	**0.30**	33.2	2	51.0	0.30	66.3
	Product-6	**3.2**	**0.30**	4.2	2	6.4	0.30	8.3

Based on the ΔV and the propulsion system type

From the Launch Vehicle description

Based on the Mass Margin equation

CONCLUSION

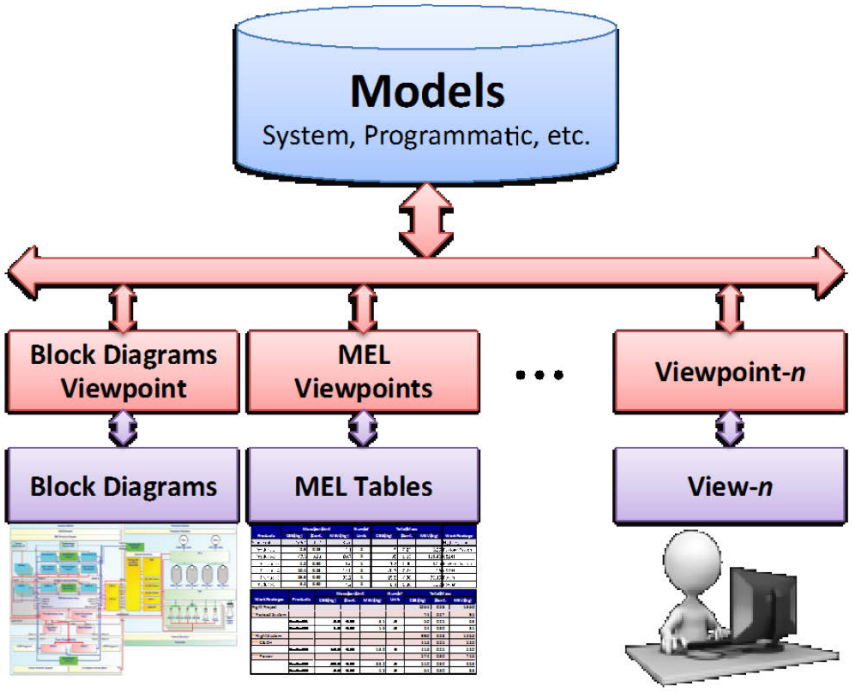
Conclusion

Consistency

- Enforced by having a single-source-of-truth, the models

Correctness

- Enforced through verification checks and reviews from various viewpoints of the Models



Used in the EHM project to help design three different mission concepts in just three months with a high degree of confidence in the consistency, correctness and even completeness.