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Bridging the Gap Between Architects, Engineers and Other Stakeholders in Complex and Multidisciplinary Systems - a Holistic, Inclusive and Interactive Design Approach

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Have you ever experienced …?

- Back-and-forth system optimisation because neighbouring systems have changed
- Difficulties to communicate in the negotiation of design margins between systems
- Cascaded requirement with untraceable underlying rationale

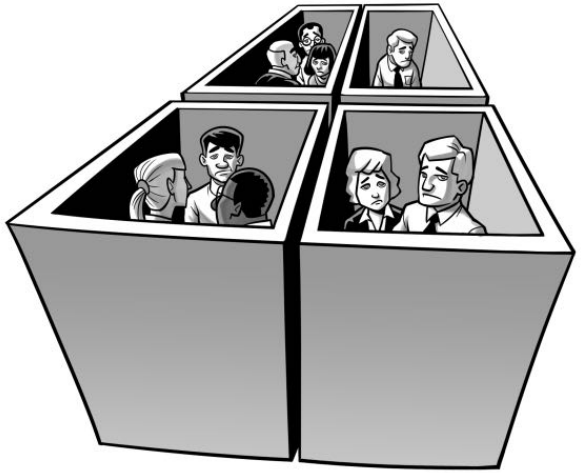
Imagine now you have this…

- A holistic interactive design tool that everyone can use without specific ‘domain’ knowledge

Agenda

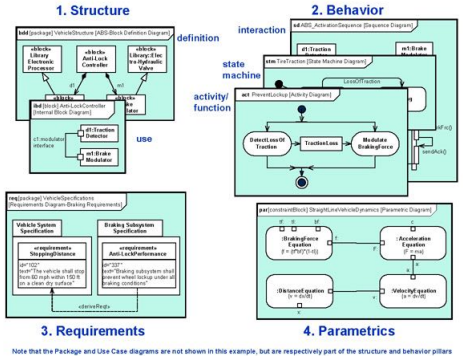
1. Why is collaboration so hard?
2. What do we want anyway?
3. MBSE Framework
4. Modelling
5. Chord Diagram Interactive Design Tool
6. Conclusions

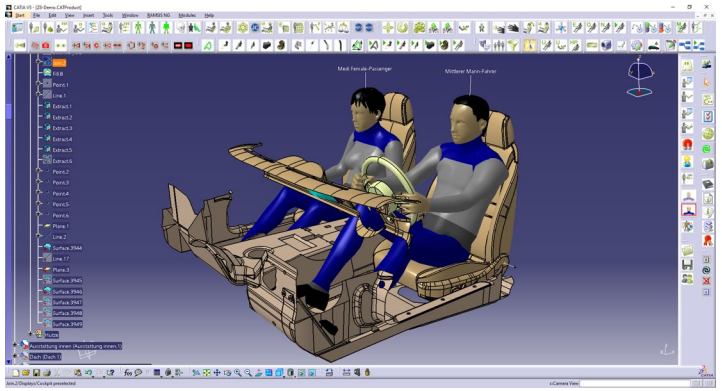
Why is collaboration so hard?



Siloed goals

https://www.customerbliss.com/wp-content/uploads/2017/04/bliss-silos.png





Different tools and languages

https://www.omgsysml.org/
https://www.3ds.com/

What do we want anyway?

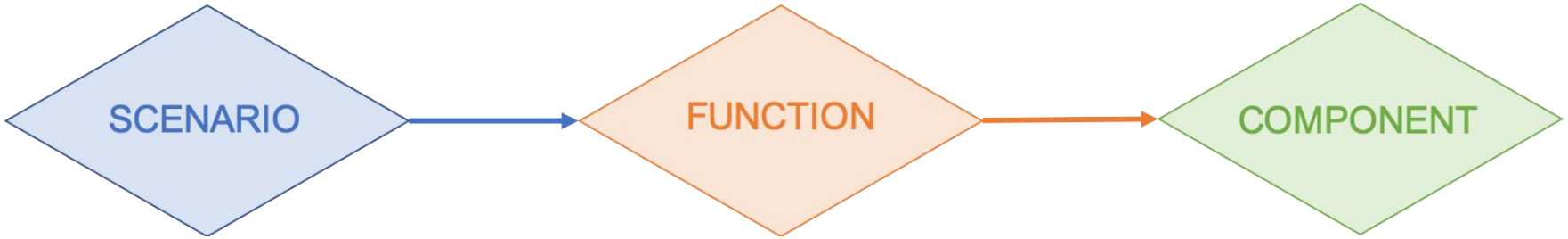
Design Optimisation

https://www.aerosociety.com/

Collaboration for Everyone

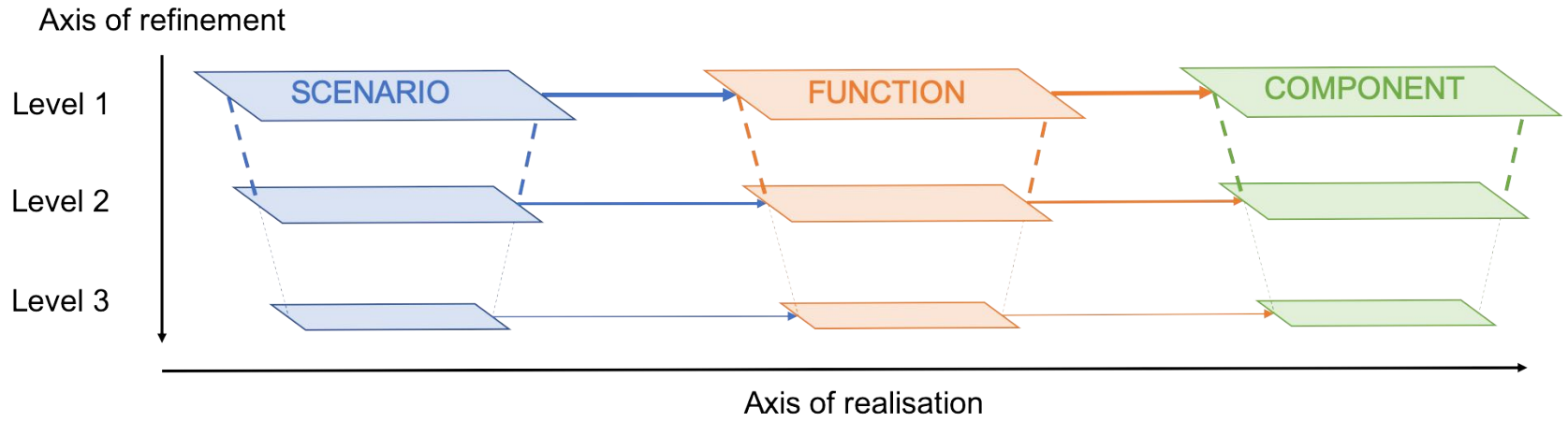
CAVE2

MBSE Framework



‘Scenario’ describes the purpose of the system.
‘Function’ describes how the system can achieve the ‘scenario’.
‘Component’ describes how the equipment can achieve the ‘function’.

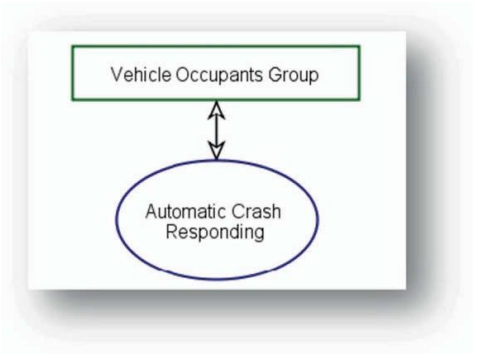
MBSE Framework (Cont.)



Axis of realisation - from objectives to physical operation
Axis of refinement - from high to low level of abstraction

MBSE Framework (Cont.)

- OPM (Dori, 2002)
- Things - object or process
- Relationships - structural links or procedural links



Fundamental structural links

modality	aggregation-participation	exhibition-characterization	generalization-specialization	classification-instantiation
Graphics – Object-Process Diagram (OPD)	Whole / Part	Exhibitor / Attribute	General / Specialization	Class / Instance
Textual – Object-Process Language (OPL)	**Whole** consists of **Part.**	**Exhibitor** exhibits **Attribute.**	**Specialization** is a **General.**	**Instance** is an instance of **Class.**

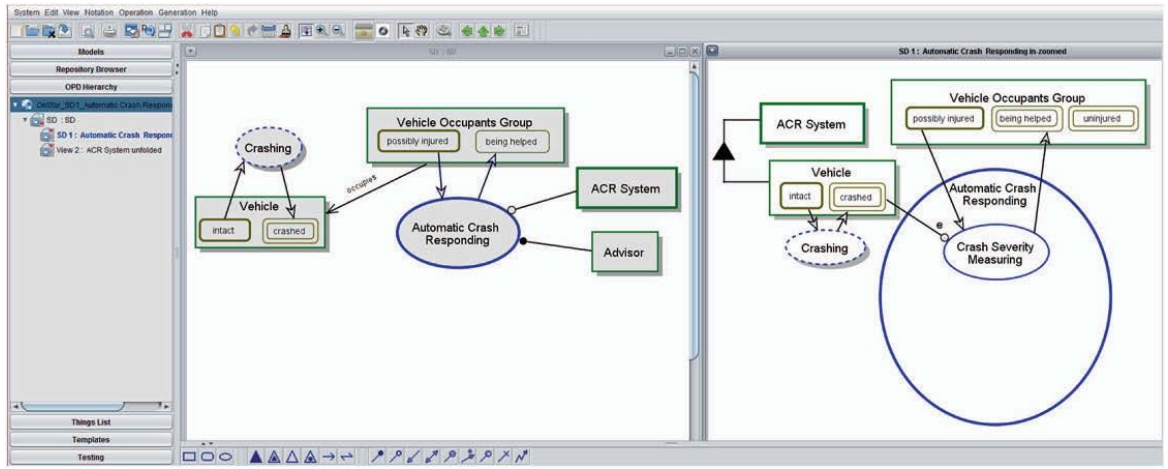
Procedural transforming links

consumption link	result link	effect link	in-out link pair
Consumee / Consuming	Creating / Resultee	Affectee / Affecting	Affectee (input state, output state) / State Changing
Consuming consumes **Consumee.**	**Creating** yields **Resultee.**	**Affecting** affects **Affectee.**	**State Changing** changes **Affectee** from **input state** to **output state.**

Model-Based Systems Engineering with OPM and SysML, Dov Dori, 2016

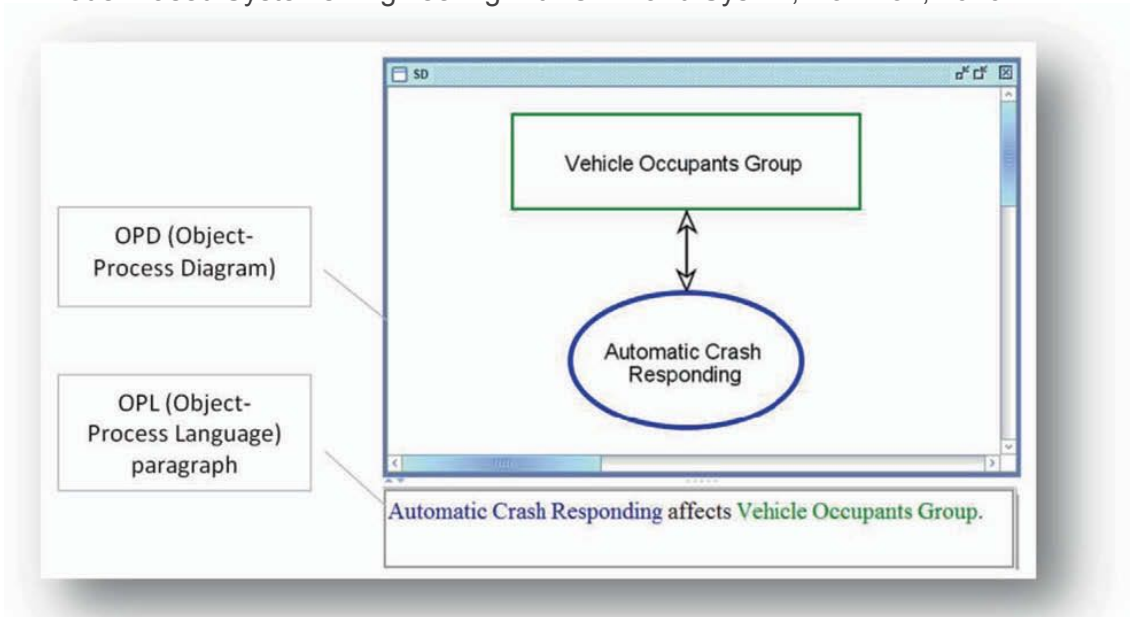
MBSE Framework (Cont.)

Model-Based Systems Engineering with OPM and SysML, Dov Dori, 2016



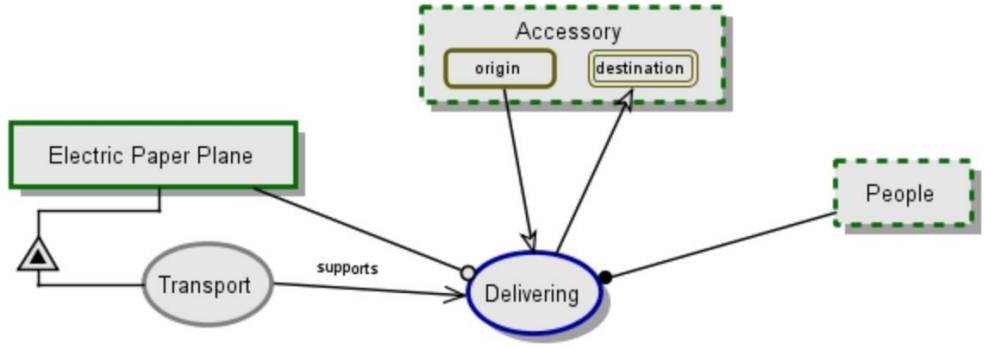
In-zooming supports axis of refinement

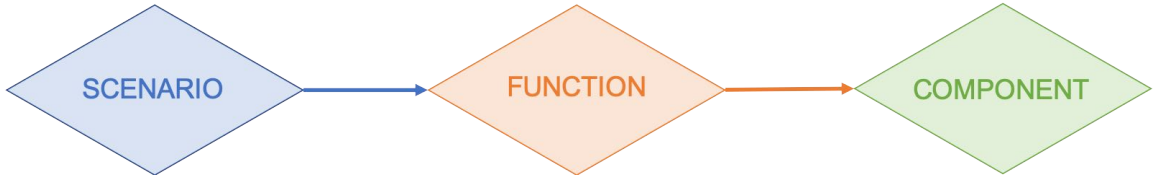
Model-Based Systems Engineering with OPM and SysML, Dov Dori, 2016



Dual modality for enhanced accessibility

Modelling

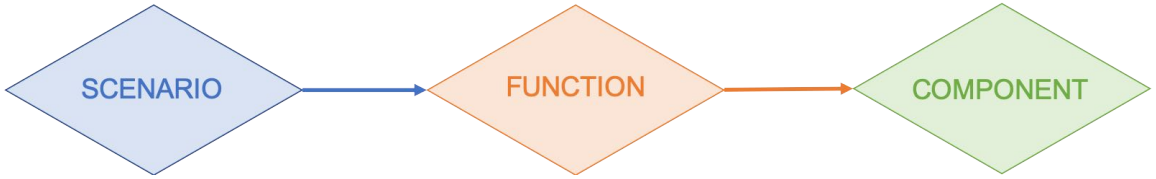


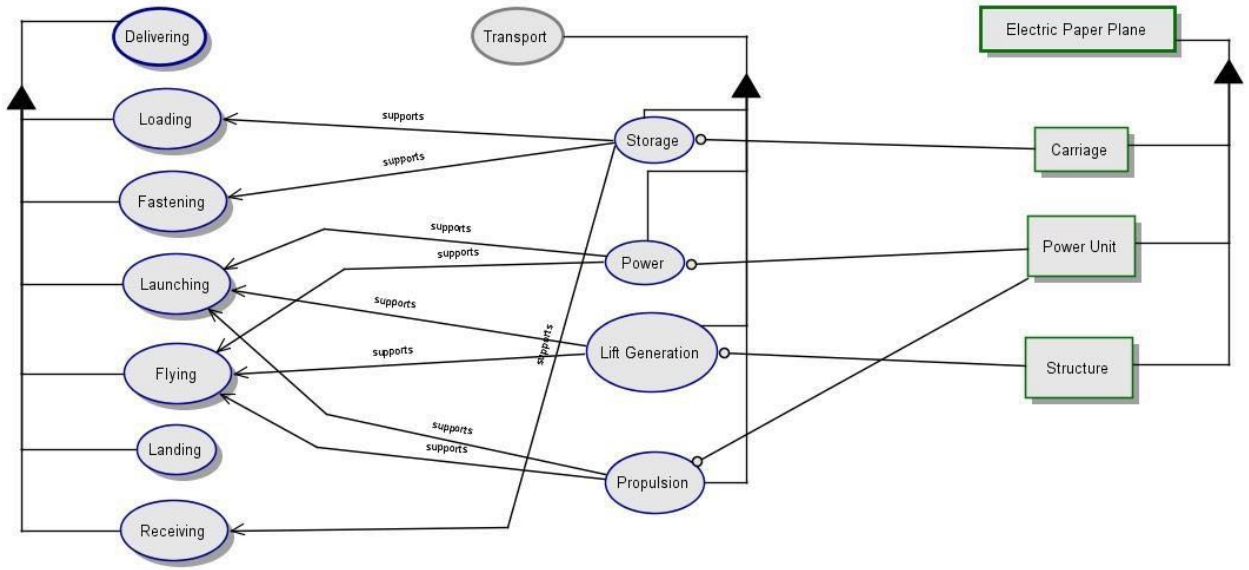


Electric Paper Plane is physical.
Electric Paper Plane exhibits **Transport**.
Transport supports **Delivering**.
Accessory is environmental and physical.
Accessory can be **origin** or **destination**.
origin is initial.
destination is final.
People is environmental and physical.
People handles **Delivering**.
Delivering is physical.
Delivering requires **Electric Paper Plane**.
Delivering changes **Accessory** from **origin** to **destination**.

Scenario ‘Delivering’ modelled as Process.
Function ‘Transport’ modelled as Process.
Component ‘Electric Paper Plane’ modelled as Object.

Modelling (Cont.)



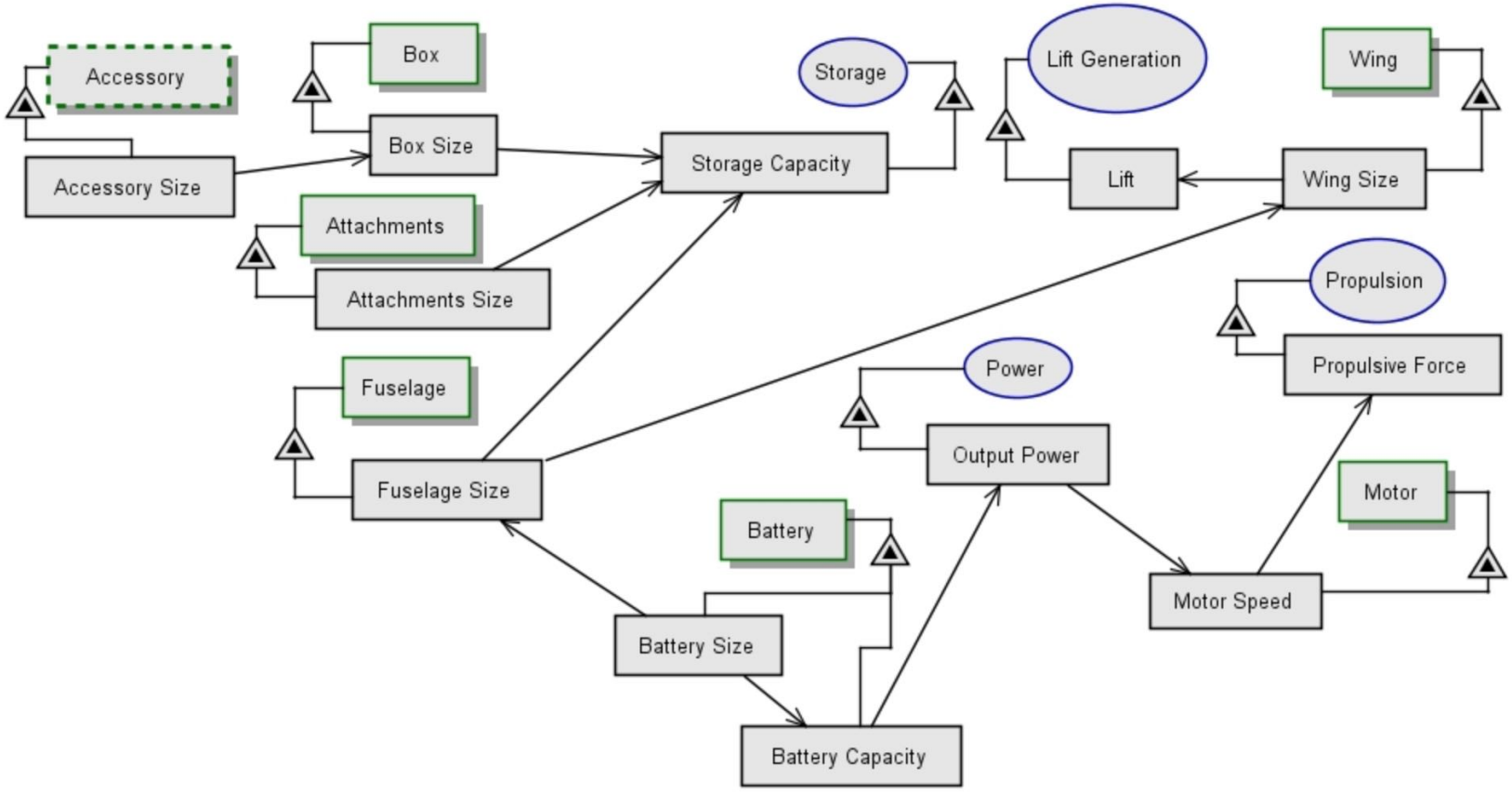


Electric Paper Plane is physical.
Electric Paper Plane consists of **Carriage**, **Power Unit**, and **Structure**.
- **Carriage** is physical.
- **Power Unit** is physical.
- **Structure** is physical.

Delivering is physical.
Delivering consists of **Loading**, **Launching**, **Flying**, **Landing**, **Receiving**, and **Fastening**.
- **Loading** is physical.
- **Launching** is physical.
- **Flying** is physical.
- **Landing** is physical.
- **Receiving** is physical.
- **Fastening** is physical.

Transport consists of **Storage**, **Lift Generation**, **Propulsion**, and **Power**.
- **Storage** supports **Fastening**.
- **Storage** supports **Loading**.
- **Storage** supports **Receiving**.
- **Storage** requires **Carriage**.
- **Lift Generation** supports **Flying**.
- **Lift Generation** supports **Launching**.
- **Lift Generation** requires **Structure**.
- **Propulsion** supports **Flying**.
- **Propulsion** supports **Launching**.
- **Propulsion** requires **Power Unit**.
- **Power** supports **Flying**.
- **Power** supports **Launching**.
- **Power** requires **Power Unit**.

Modelling (Cont.)

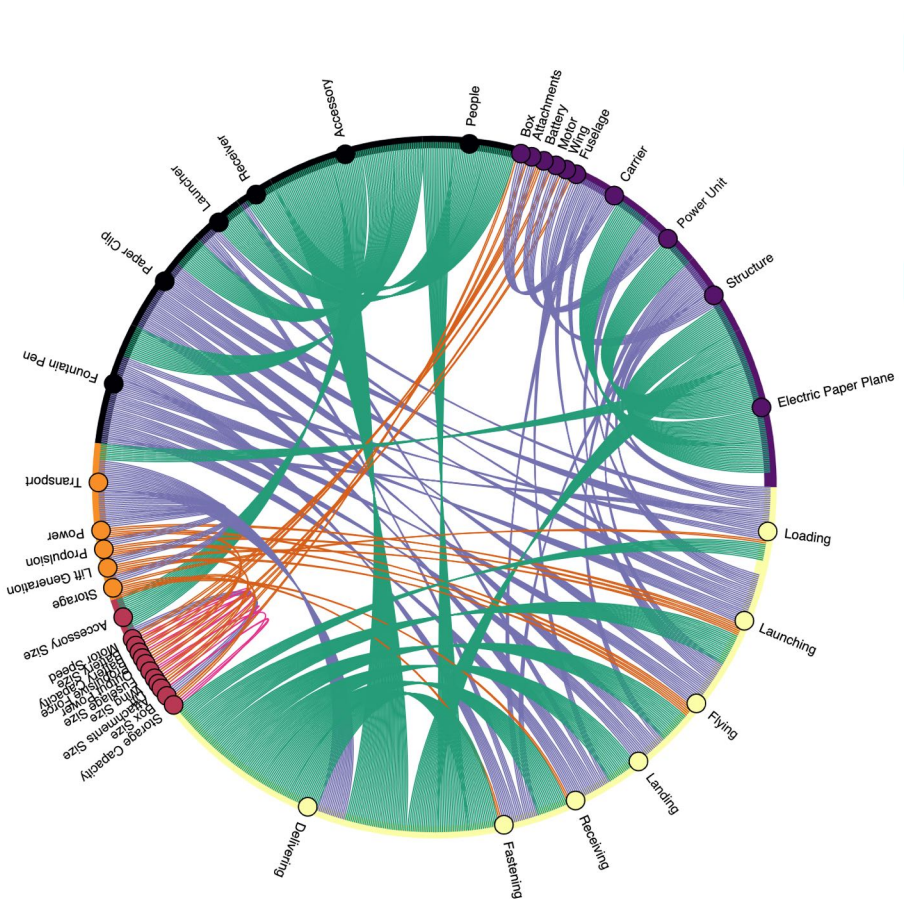


Accessory is environmental and physical.
Accessory exhibits Accessory Size.
    Accessory Size relates to Box Size.
Box is physical.
Box exhibits Box Size.
    Box Size relates to Storage Capacity.
Attachments is physical.
Attachments exhibits Attachments Size.
    Attachments Size relates to Storage Capacity.
Battery is physical.
Battery exhibits Battery Capacity and Battery Size.
    Battery Capacity relates to Output Power.
    Battery Size relates to Battery Capacity.
    Battery Size relates to Fuselage Size.
Motor is physical.
Motor exhibits Motor Speed.
    Motor Speed relates to Propulsive Force.
Wing is physical.
Wing exhibits Wing Size.
    Wing Size relates to Lift.
Fuselage is physical.
Fuselage exhibits Fuselage Size.
    Fuselage Size relates to Storage Capacity.
    Fuselage Size relates to Wing Size.
Lift Generation exhibits Lift.
Propulsion exhibits Propulsive Force.
Power exhibits Output Power.
    Output Power relates to Motor Speed.
Storage exhibits Storage Capacity.

Parameters modelled as object, exhibited by its parent thing. Tagged structural link to establish relationships between parameters.

Chord Diagram Interactive Design Tool

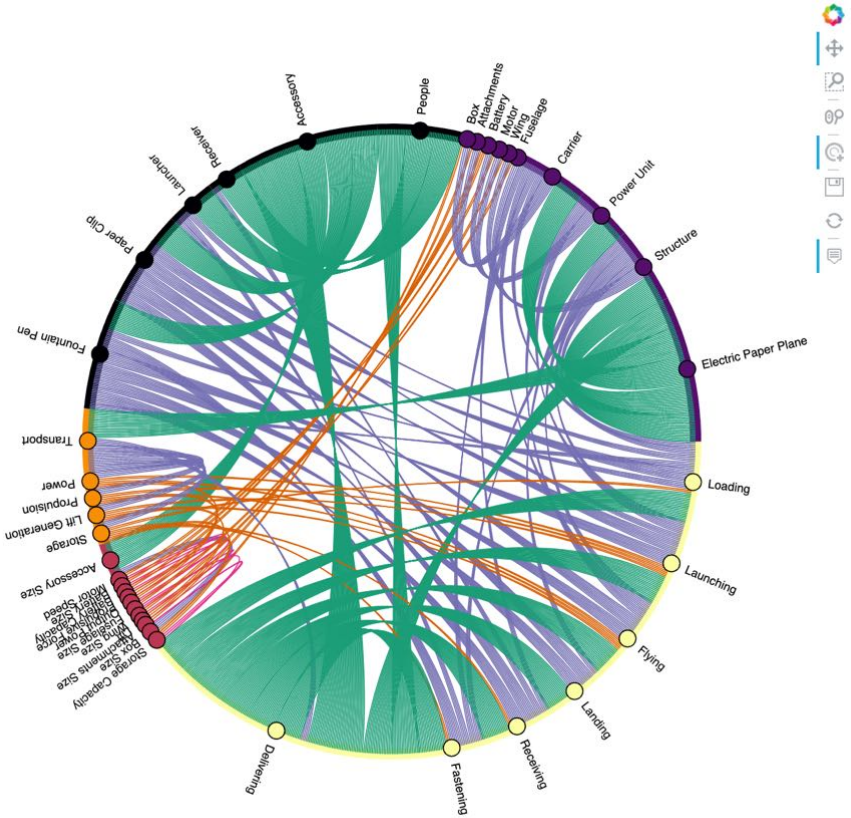
- Chord diagram is used to display the many interrelationships within a system
- A chord between two nodes signifies there is a relationship
- Width of chord can be weighted with a custom function
- Node span is the aggregate width of its chords

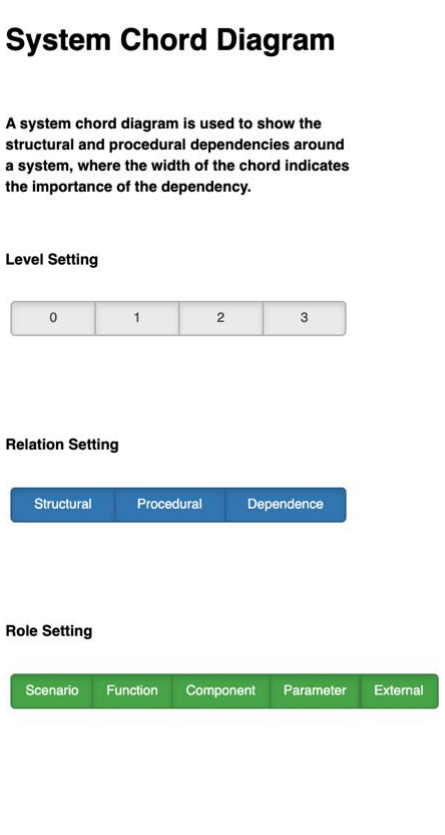


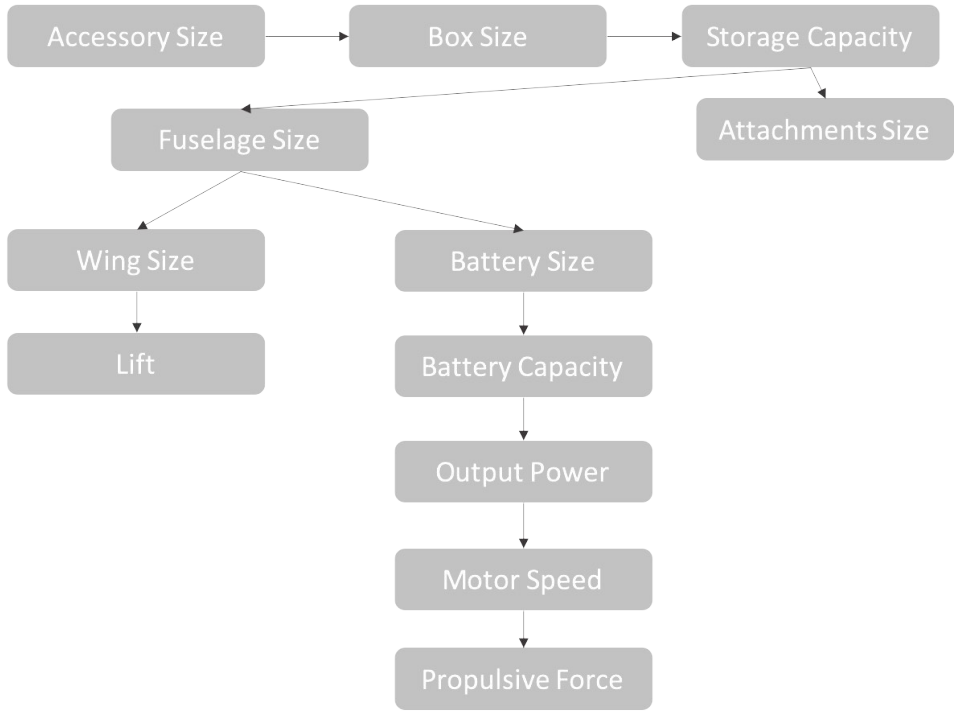
Chord Diagram Interactive Design Tool (Cont.)

- Models in OPCAT are in XML format
- Python package beautiful soup is used to parse the XML
- Python package holoviews and bokeh are used to generate interactive chord diagram with some UI

Chord Diagram Interactive Design Tool (Cont.)







Demo (Parameters View)

Conclusion

- A simplified MBSE framework, OPM and a few open source python packages to create an interactive design tool
- Real-time collaboration between different stakeholders in conceptual design stage
- Useful insights can be extracted much earlier

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