Systems Thinking for Design

Session 10

INDIAN INSTITUTE OF INFORMATION TECHNOLOGY,
DESIGN AND MANUFACTURING,
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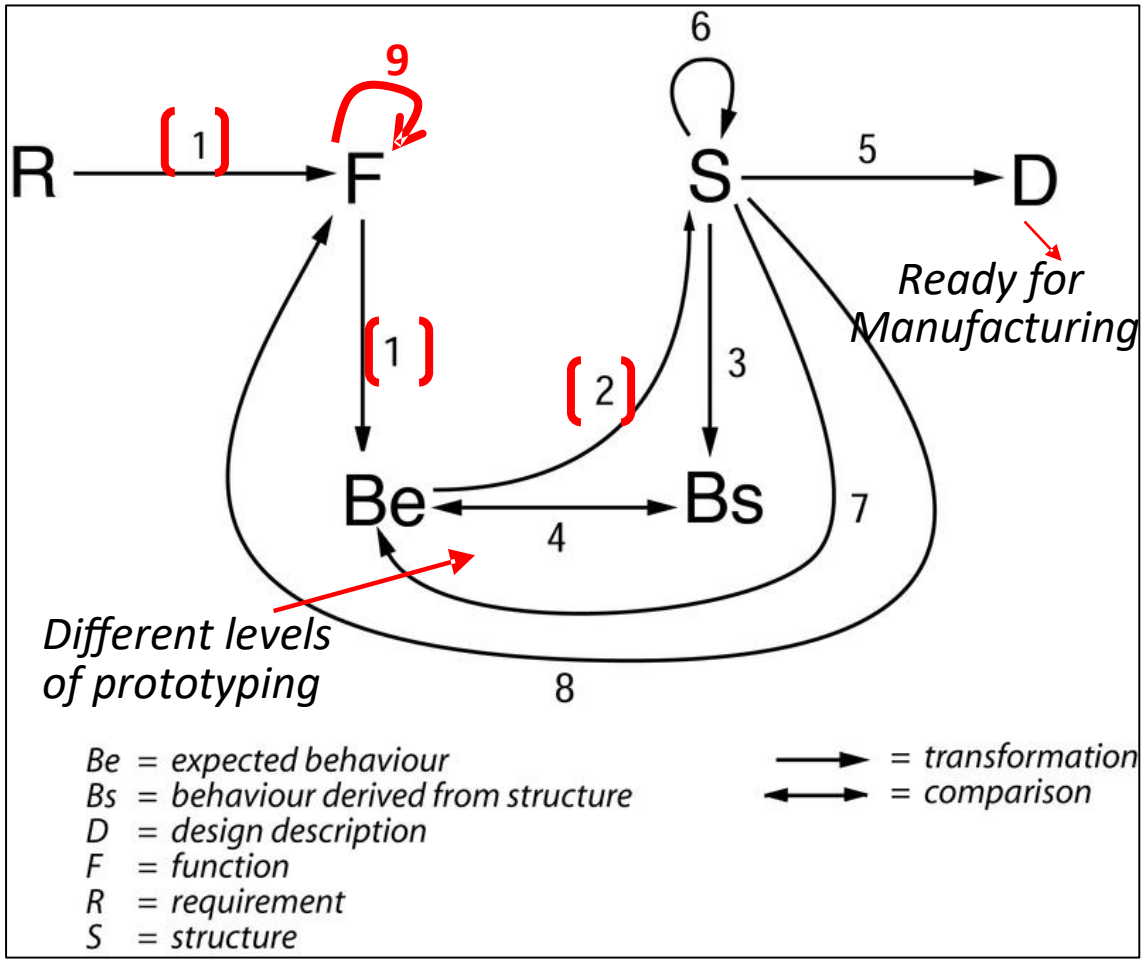
Session outline

- Why Functional Design is critical before Structural Design?
- Generating & Tweaking Structural Designs using ISM

Function-behavior-structure + (form, content, process..)



In Systems Thinking for Design we are focusing on linkages [1] and [2] that represent key stages in the fuzzy front-end of product design & innovation

Discovery-Diagnosis and Functional Architecture [9] can bring us to clarity on F and Be and their relationships

Functional Architecture can then be translated into [2] different structural designs

[3,4,5] are part of detail design (core engineering design) – involves CAD/FEM/Simulation

[6] will be the component interaction matrix (also known as Design Structure Matrix or Product Architecture - discussed in today's session)

Session outline

- Why Functional Design is critical before Structural Design?
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Generating structural designs (1/3)

Use this matrix to derive the structural options (sub-systems) for critical functions

	Functions	Option 1	Option 2	…	Option J
F1	Functions with High D-R, Low D+R	A1	A2	…	Aj
F2	Functions with D-R close to 0, High D+R	B1	B2	…	Bj
F3	Functions with Negative D-R and Low D+R	…	…	…	…
F4	Functions with D-R close to 0, D+R close to 0	K1	K2	…	Kj

Pick the most appropriate technology for the critical functions

Each column could be filled taking needs/preferences of a key stakeholder – customer, enterprise, regulatory body

Generating structural designs (2/3)

- Once the high-level product architecture is defined, then use the below matrix to detail other components in the structure, i.e. create the detailed component list

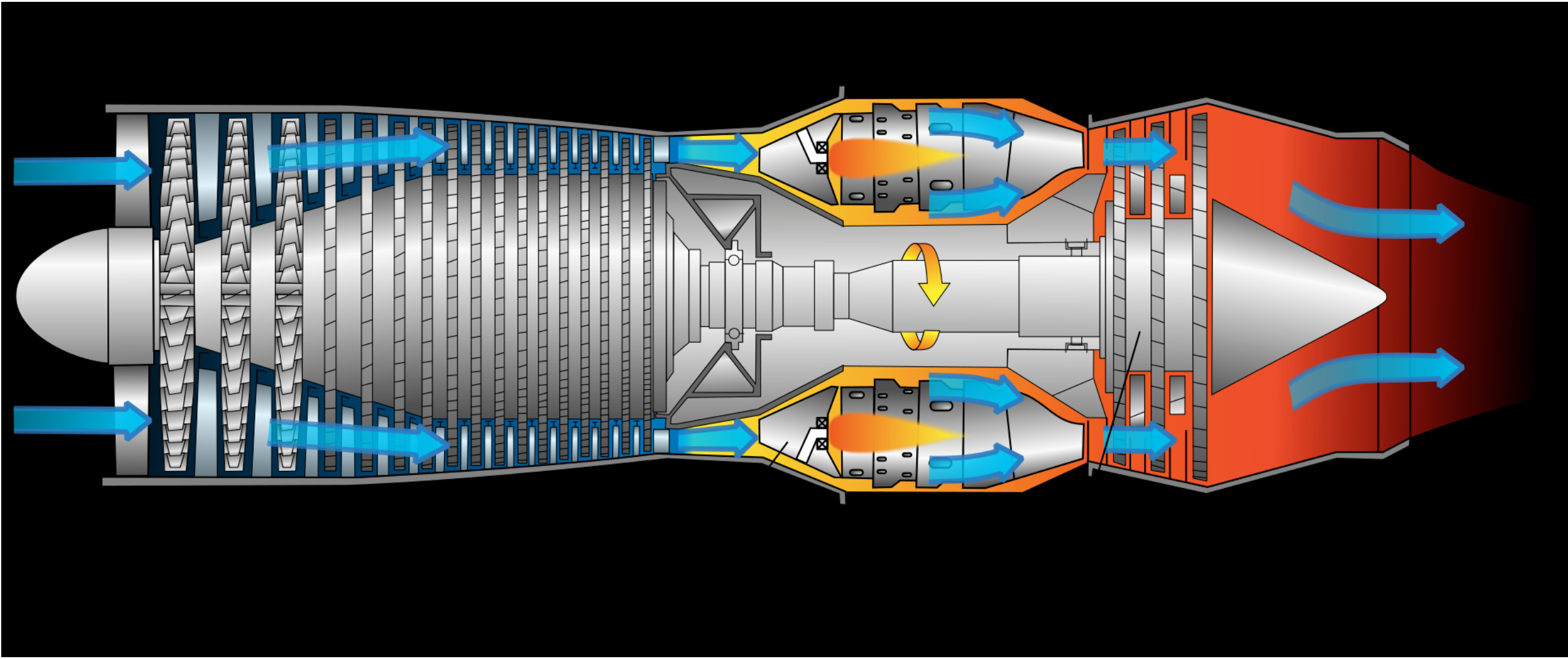
Functions	Component 1	Component 2	…	Component J
Function 1	†	†	…	†
Function 2		†	…	
Function …	†		…	
Function k			…	†

Generating structural designs (3/3)

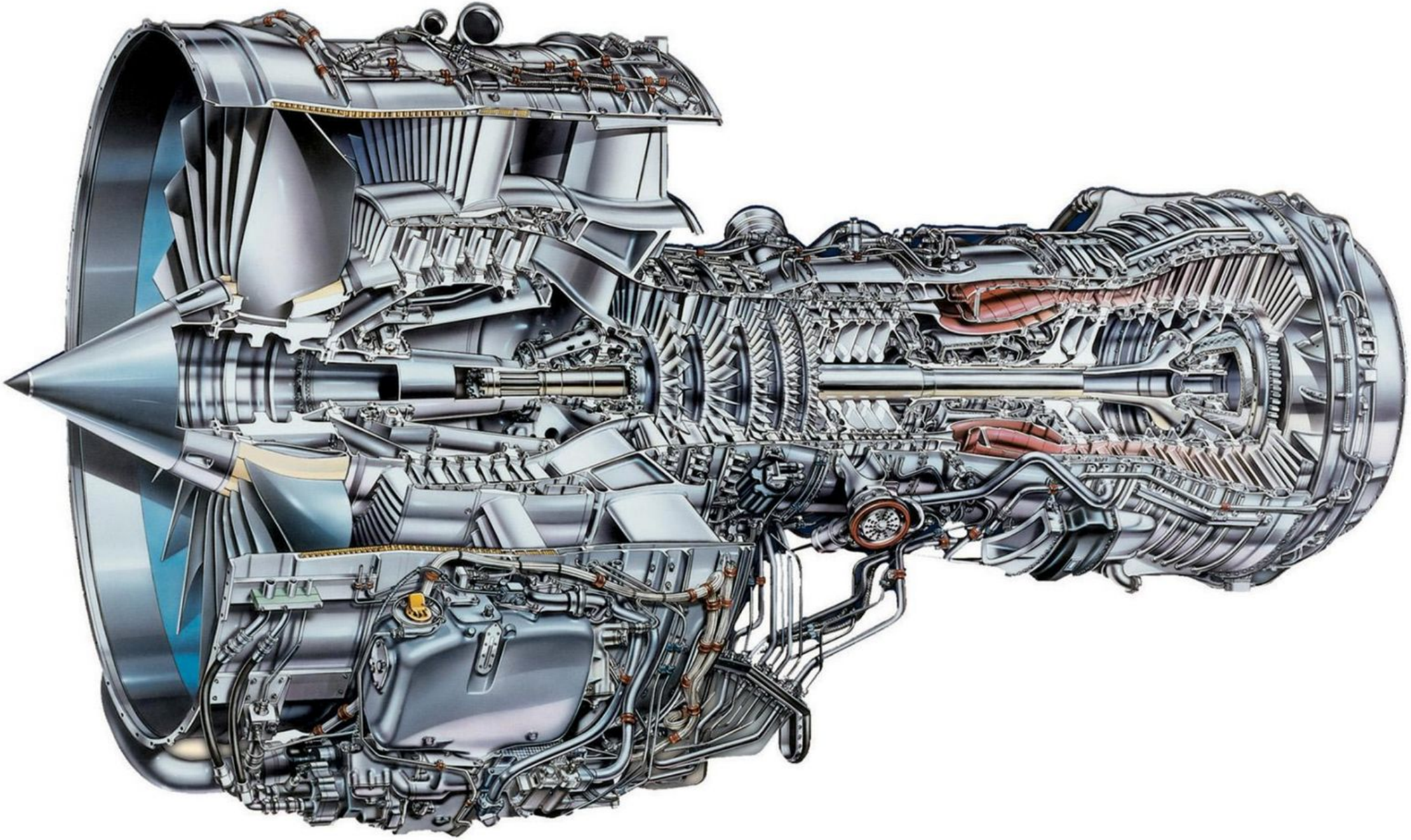
- Develop the adjacency matrix of component interaction [6].
- Applying ISM method to this matrix can reveal properties of the structural design. This is also called as Design Structure Matrix (DSM) / Product Architecture
- This is where detail engineering design knowledge about materials, thermal properties, mechanisms, electronics, data structures, will be required.

Functions	Component 1	Component 2	…	Component J
Component 1	1	0		1
Component 2	0	1		1
…	0		1	
Component J	0	1		1

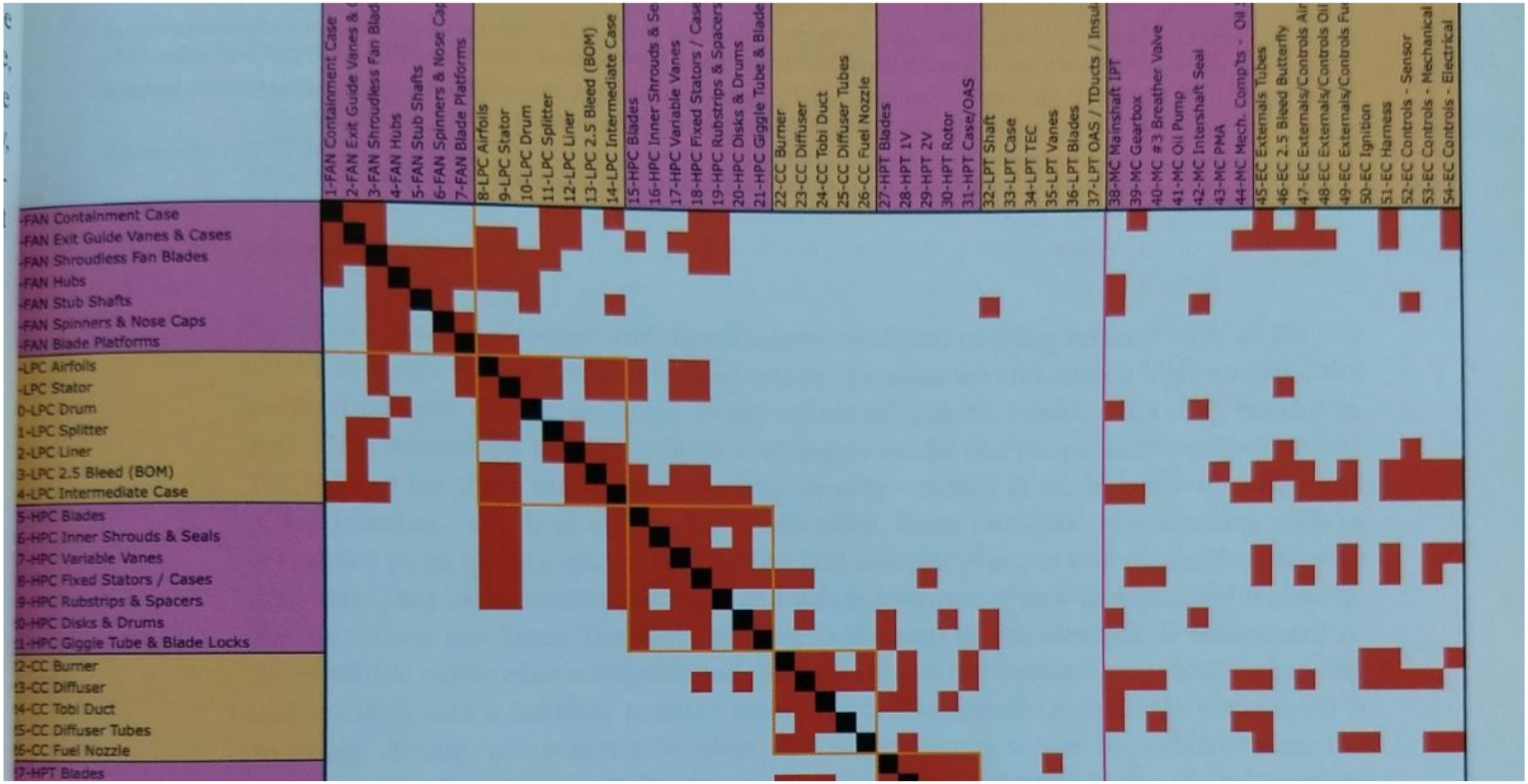
Jet engine – key subsystems



Jet engine – actual implementation!



Examples of DSM: Pratt & Whitney Jet Engine System Architecture; Source: Eppinger & Browning (2012)



Reference video – Real engineering https://youtu.be/Sf6H8kSunRA

Car – climate control

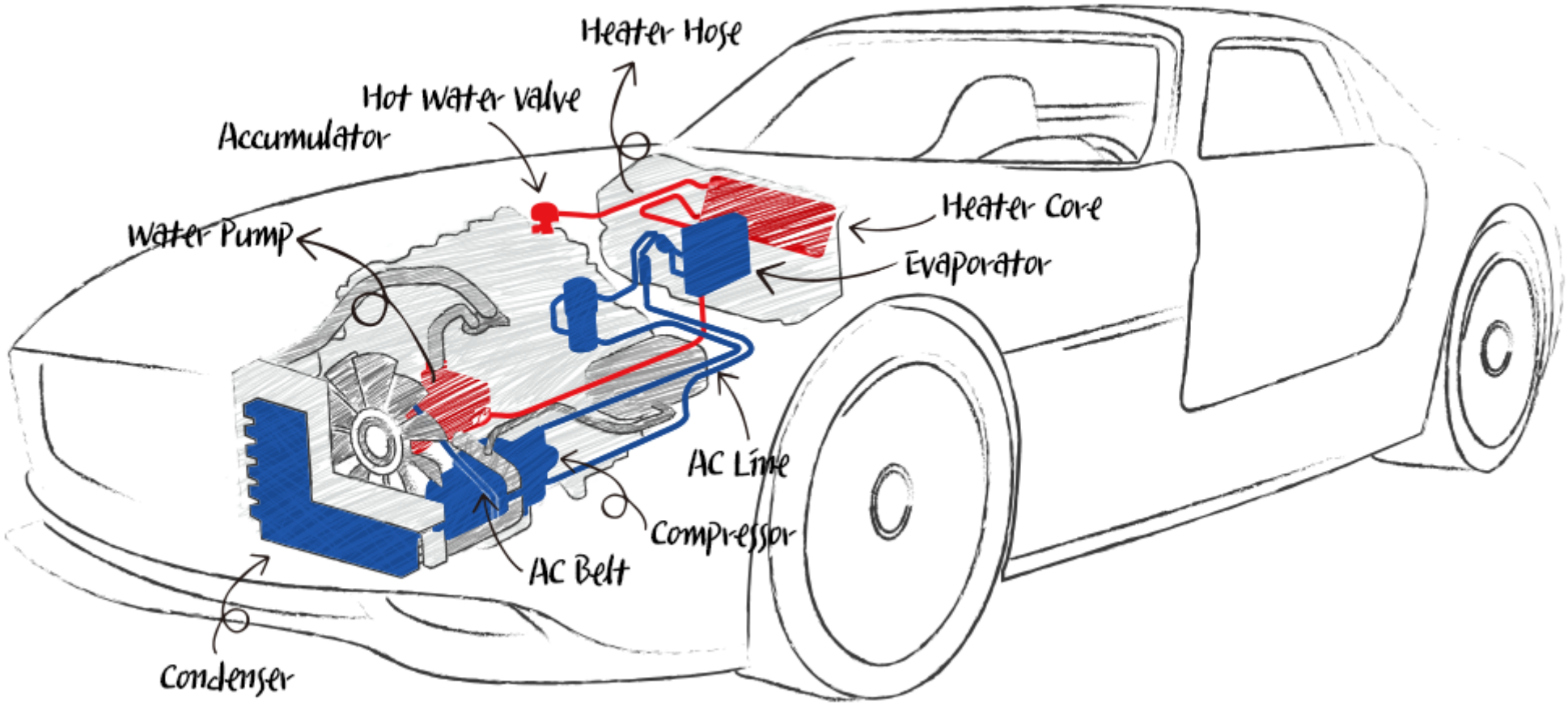
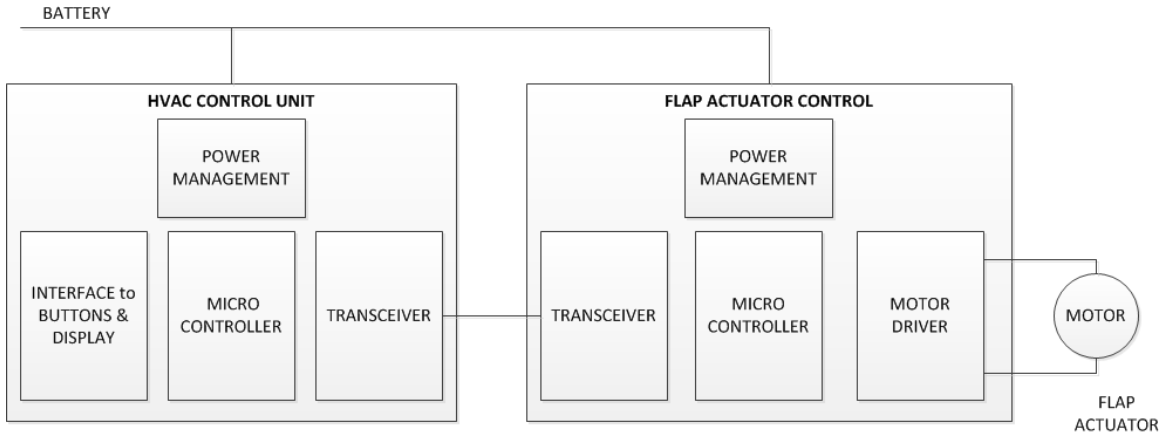
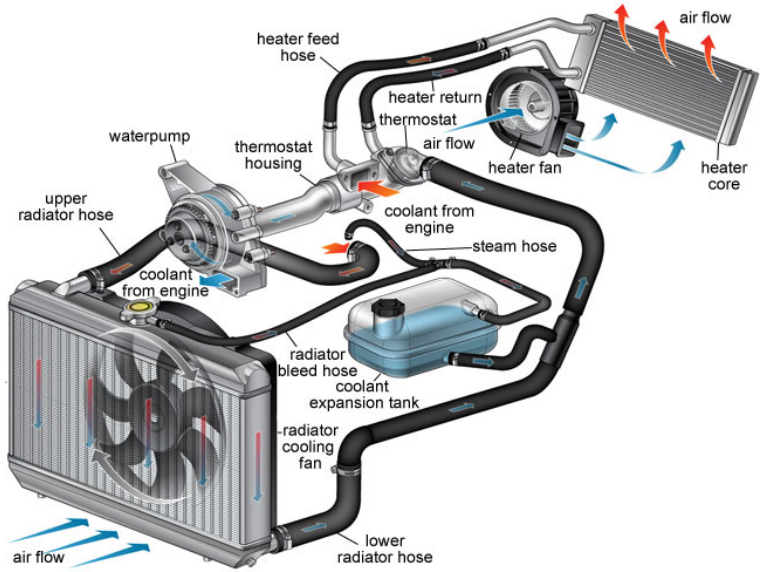


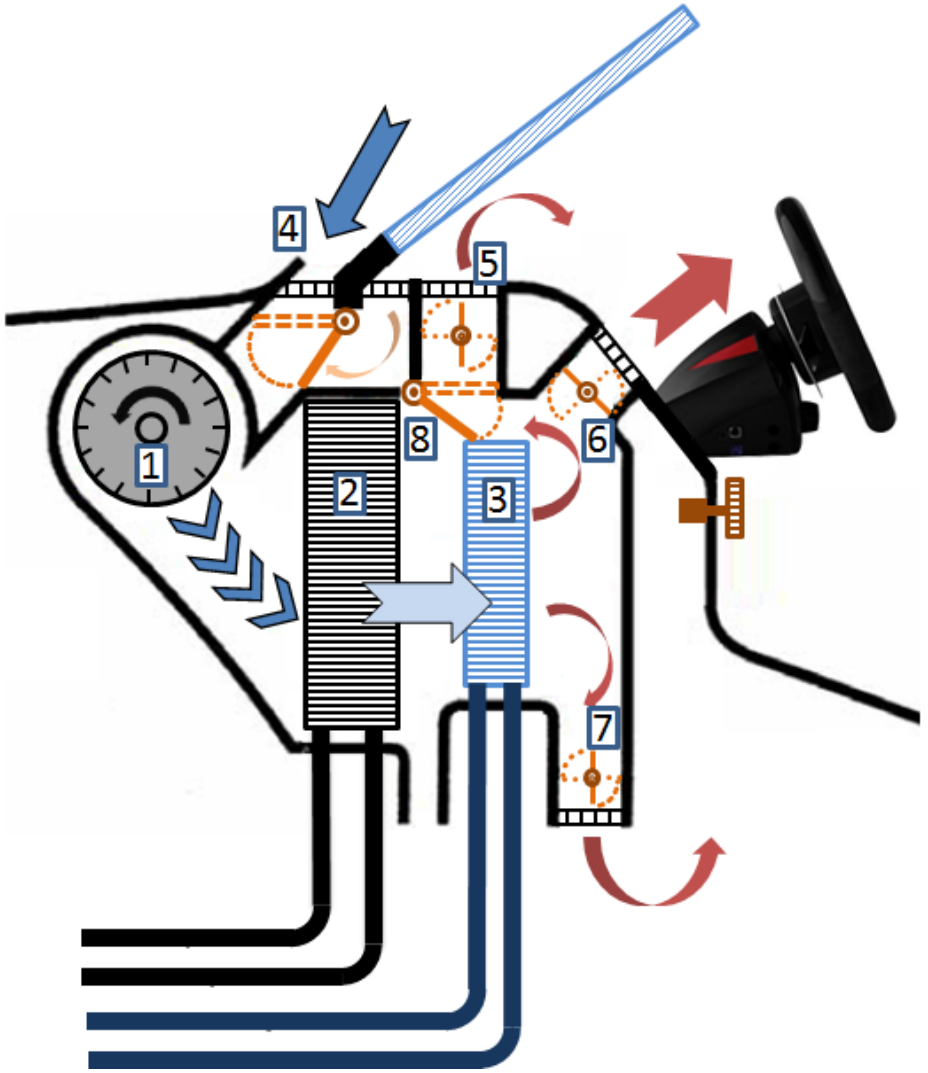
Image courtesy: https://www.lghvacstory.com/hvac-on-the-move-land-air-sea-and-space/

Car – climate control contd…



Remote control of flap actuator motor

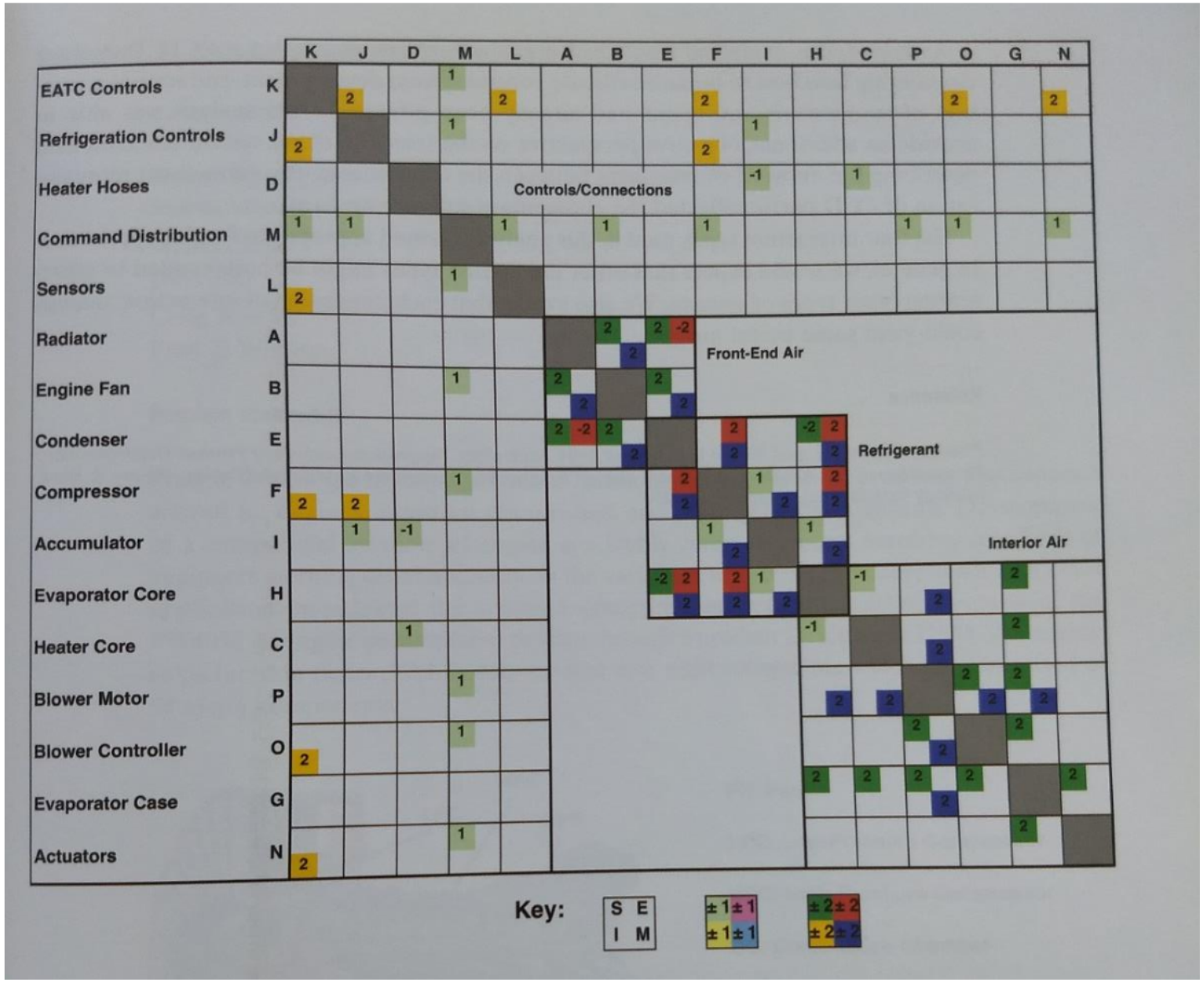




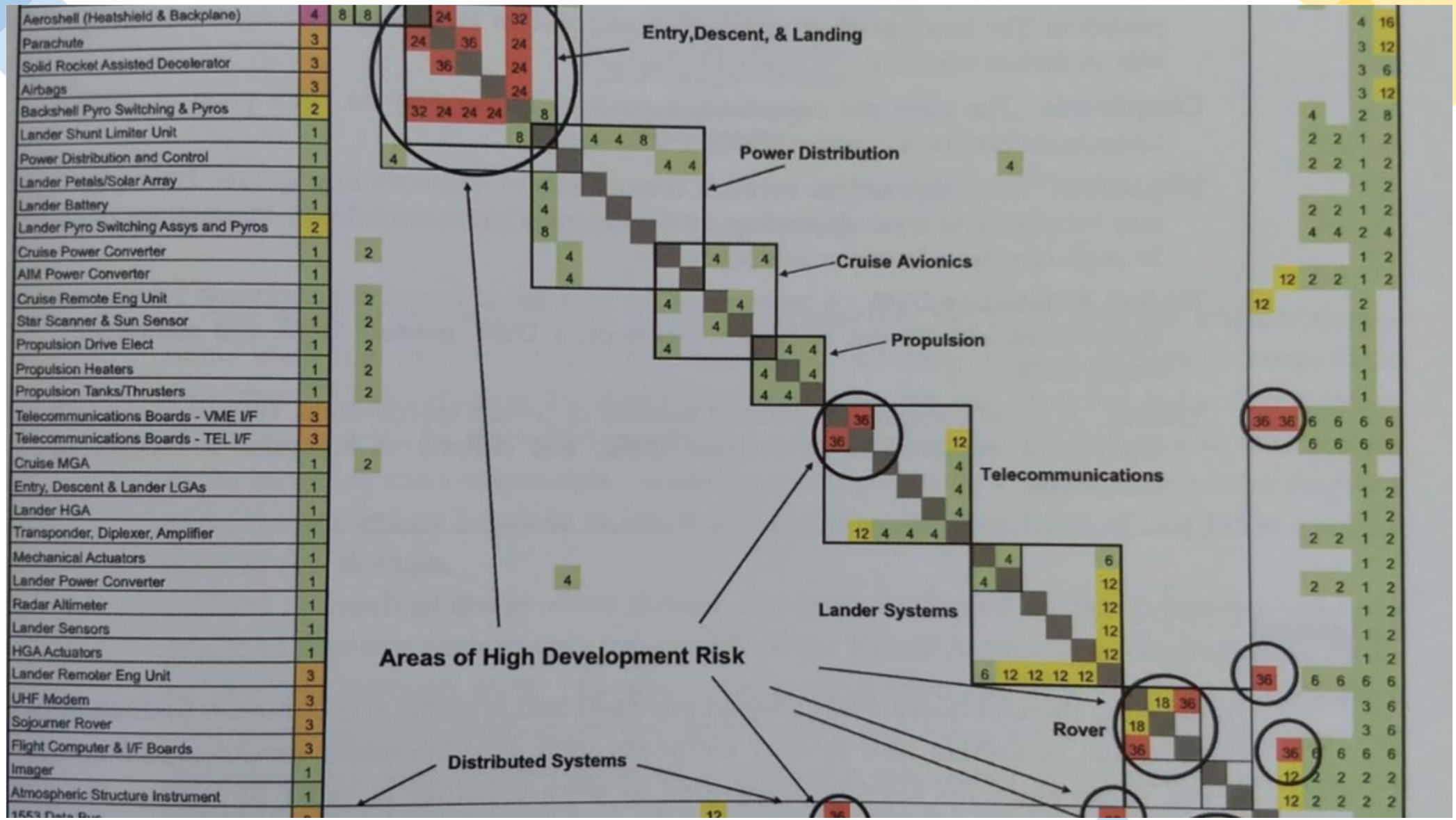
Car HVAC

Image courtesy: https://e2e.ti.com/blogs_/b/behind_the_wheel/posts/understanding-flap-actuators-and-what-drives-them-in-automotive-hvac-systems

Composite DSM: Ford Climate Control;
Source: Eppinger & Browning (2012)



DSM for Risk Assessment: Mars Rover; Source: Eppinger & Browning (2012)



Tweaking a design: example, treadmill

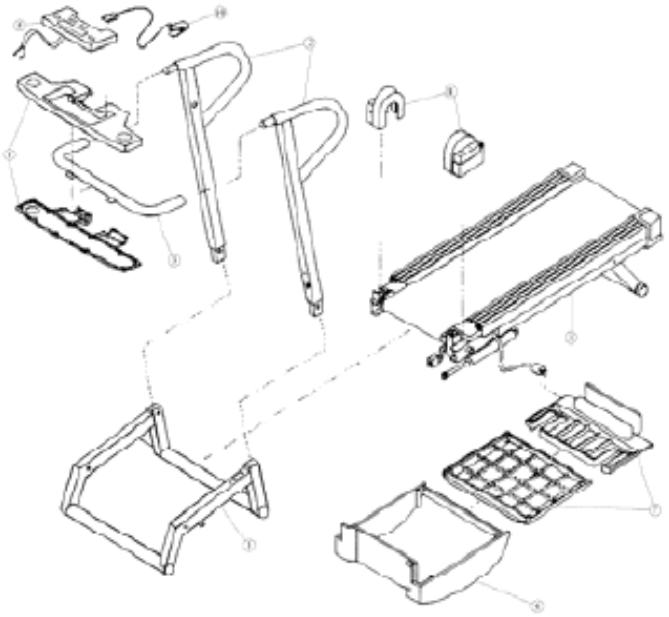


Fig. 1. The explosive view of a treadmill

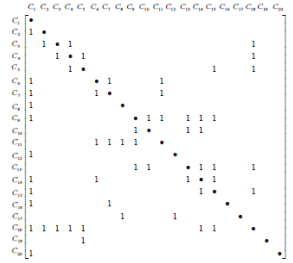


Fig. 3. Original matrix relationship for treadmill

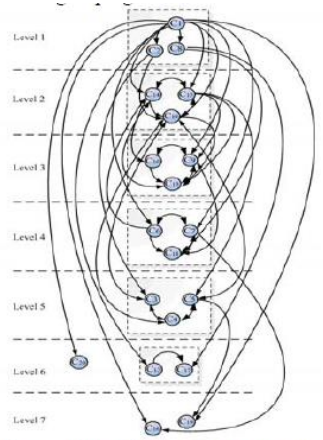
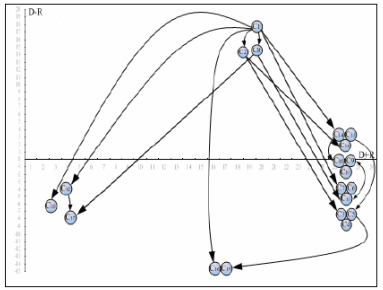


Fig. 6. Hierarchical graph of components

Fig. 8. The fordable electric treadmill



Chung-Shing Wang et al. (2006) Integrated Design Structure System for Modular Design in Products Development

ISM to guide structural design changes

$$A = \begin{array}{c|cccccccc} & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 2 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 3 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 4 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 \\ 5 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 6 & 1 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 7 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 8 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{array} \quad R = \begin{array}{c|cccccccc} & 1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 \\ 1 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 2 & 0 & 1 & 1 & 0 & 0 & 0 & 0 & 0 \\ 3 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 4 & 0 & 0 & 0 & 1 & 0 & 0 & 1 & 1 \\ 5 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & 0 \\ 6 & 1 & 0 & 0 & 1 & 0 & 1 & 1 & 1 \\ 7 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 8 & & & & & & & & \end{array}$$

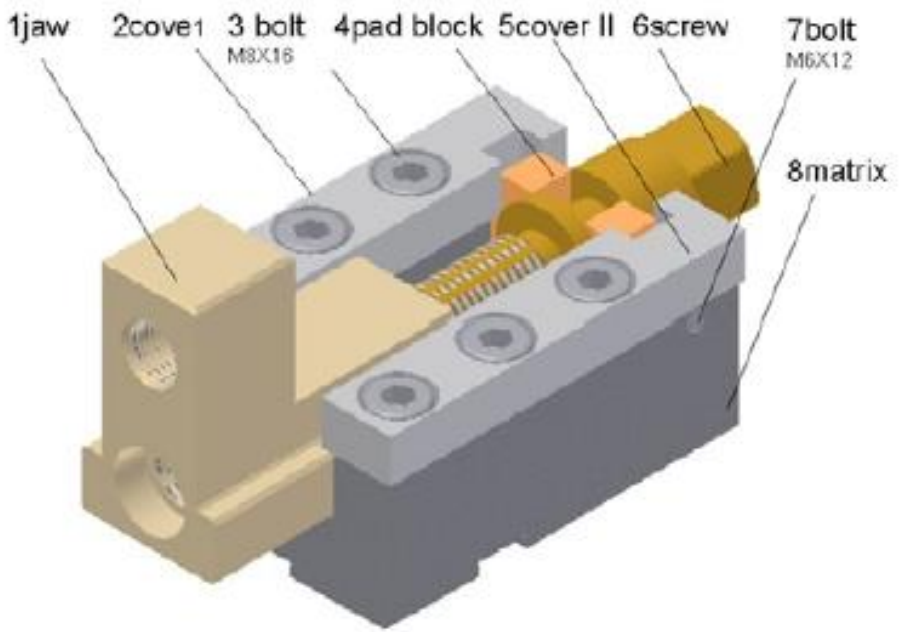


Figure 1. clamping jaw chart

Should avoid changes at this level / element as it impacts the whole system

Can alter 2 or 5 since their impact is limited

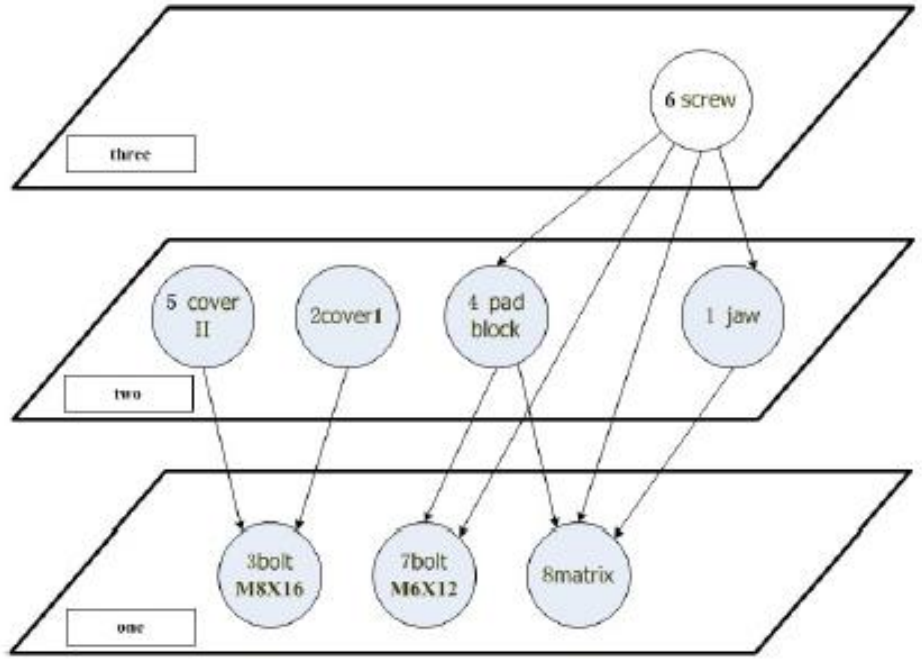


Figure 2. hierarchical model of clamping jaws diagram

DENG Xiao-lin (2012), Product Structure Analysis Method Based on the Interpretive Structural Modeling, Proceedings of 2012 International Conference on Mechanical Engineering and Material Science

Creating variety using morphology & ISM: Example, Razor design

Figure 2. Top 6 razors with strong preferences.

Table 2. Morphological analysis of 6 razor samples

Design elements	Category 1	Category 2	Category 3	Category 4
A. Body	A1	A2	A3	A4
B. Power holder	B1	B2	B3	B4
C. Power keys	C1	C2	C3	C4
D. Head	D1	D2	D3	D4

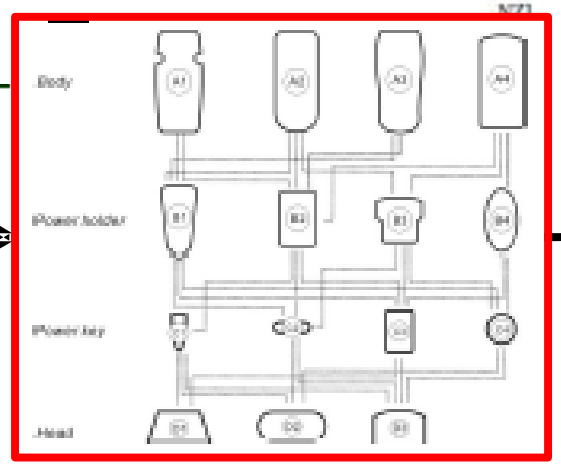


Figure 4. Several razor examples developed from ISMBA

Source: CHUNWEI CHEN (2005), The application of ISM to develop verity design solution of case host preference based products, Journal of Theoretical and Applied Information Technology, 15th January 2012. Vol. 35 No.1

Reflect on today’s class and share your comments on MS Teams