Software Safety Requirement Definition Model in JAXA's Spacecraft Projects

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Outline

1. Background

2. IV&V Process in JAXA (including safety attribute)

3. Why is Software Safety Requirement Definition Model

4. Improvement for CBCS safety requirement

5. What’s Software Safety Requirement Definition Model

6. Conclusion and Future Work

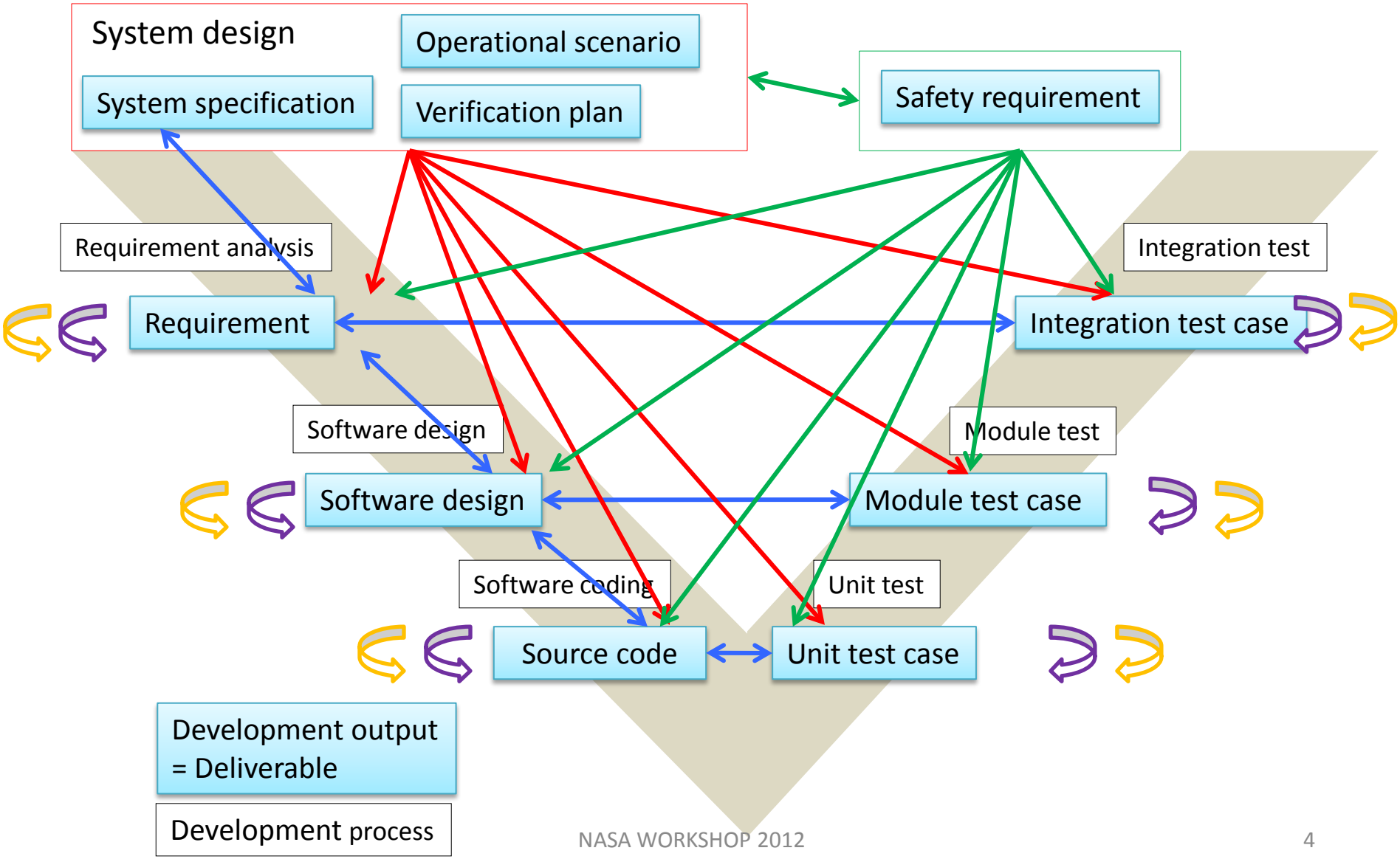
1 : Background and Purpose

"Software" is more important for software on spacecraft. Behavior and design of software effect the whole system safety. A part of spacecraft was safety review.
e.g. JEM and HTV are applied to Computer-Based Control System Safety Requirements (SSP-50038)

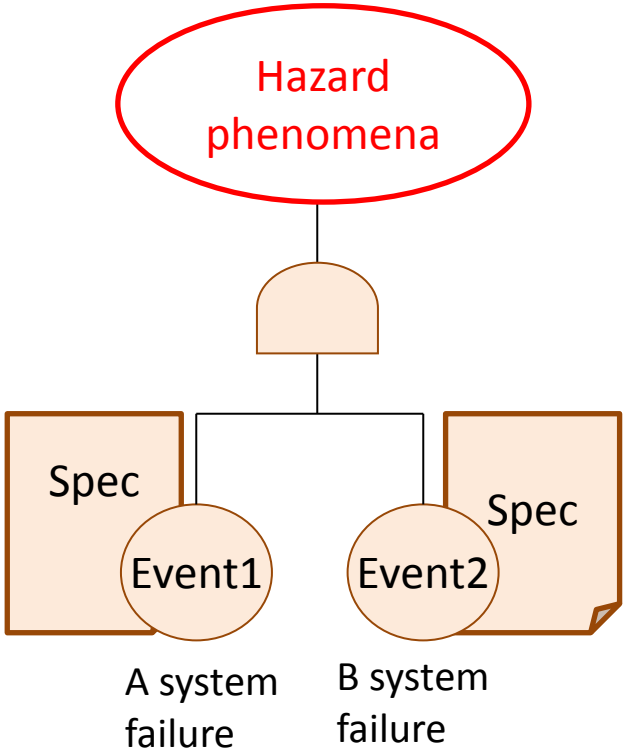
+ What's software safety requirements for each type of spacecrafts ?
+ how to realize operability and achieve mission ?
+ why the safety requirements is applied for the spacecraft ?

We need
+ to indicate coverage of safety
+ to get contexts of each safety requirements
+ IV&V methods to verify and validate the safety requirements

2. JAXA's IV&V attributes



2. Safety Attribute for IV&V



Doesn't satellite system face critical condition ?

In JAXA IV&V, Safety is not only covered with human life but also lost of satellite and mission regard as hazard.

attribute	contents	
	sub-attribute	**explanation**
Safety	sufficiency hazard analysis	Identify all the scenario that satellite system comes critical state.
	avoidance hazard	If satellite system come off nominal state, it's specification that avoid critical state and hazard.
	validation of dealing with off nominal	The system detect all failure and error, in addition system detect off nominal events and states, the specification is adequate processing (informing).

3. Why is Software Definition Model ?

To define correctly safety requirement for space craft, it's important that

1: Logically to account the effectiveness of safety requirements against the hazard.
2: To provide completeness of requirements by upper concepts
3: To conduct knowledge of safety design in past

To make Software Definition Model, we target on 3 points.

1: To guide for a beginner in software safety design.
2: To promote for a expert to essential safety.
3: Considering the contexts of each space craft,
we're able to adapt optical safety requirement.

3. Approach to construct SWDM

1. Survey safety design criteria, safety technical requirement, safety design review
2. Software safety professional board
3. Arrange safety design pattern
4. Develop software safety technical requirement
5. Make the checklist of software assessment

- safety design criteria
  DO-178B, IEC-61508,
  ISO-2626, IEC-60880,DS/EN-50128
- safety technical requirement（SSP-50038(CBCS), AIR FORCE SPACE COMMAND MANUAL））
- safety design review
  （JEM, HTV, rocket, satellite）

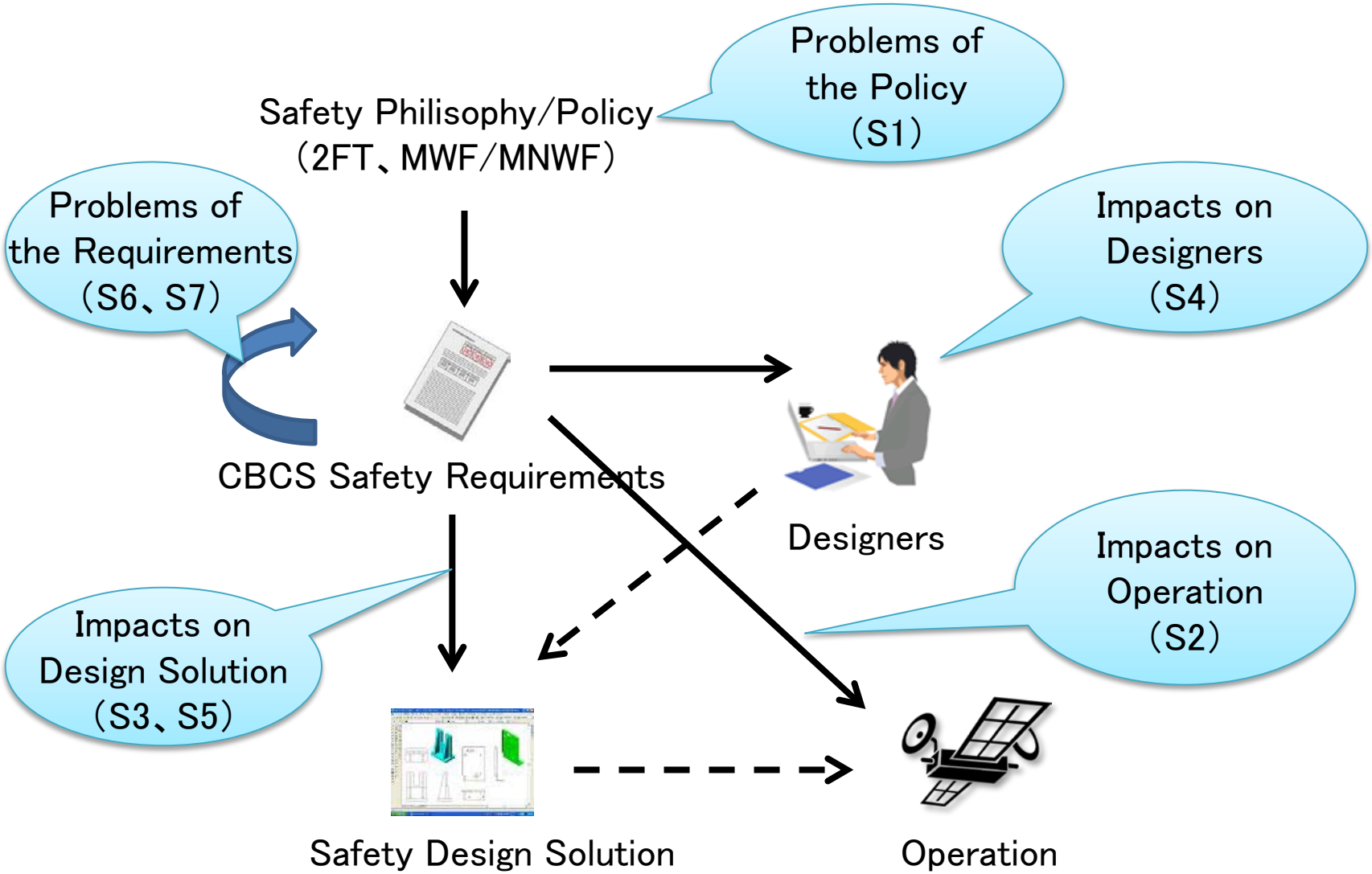
Discuss CBCS safety professional, identify knowledge and improvement of safety design pattern, safety technical requirement, operation.

Arrange software design pattern about safety requirement that is applied to spacecraft is effectiveness.

Consider safety requirements that software should be satisfied based on the improvement of CBCS safety requirements.

Arrange safety assessment items of spacecraft software from discussion points in safety review.

4. Classification of Problems on CBCS Safety Requirements



4. Chart of Problems on CBCS Safety Requirements

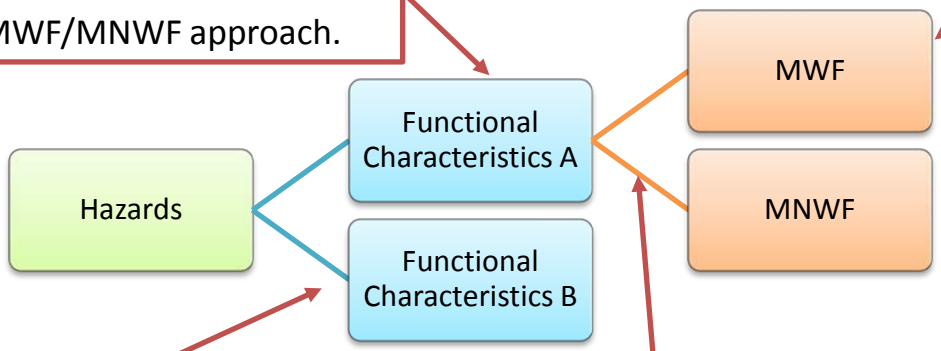
Classification	Problems	Approach to Solution
S1 MWF/MNWF	S11 Validity of protection by independence is unclear.	
	S12 MWF/MNWF is hard to identify.	
	S13 Requirements for the deactivated MWF or activated MNWF	
	S14 Safety measures against the systematic failure	
S2 Operability	S21 Operability is lowered by a number of prerequisite checks.	
	S22 Conflict with operability caused by too many commands and actions	
S3 Impacts on Design Solution	S30 Adequasy of sefety requirements/design	
S4 Impacts on Designers	S40 Negative impacts on related persons' thoughts about safety requirements/safety design	
S5 Accountability for Design Solution	S50 Feasibility of requirements	
S6 Omission of Requirements	S61 Safety requirements for the monitoring function	
	S62 Response to an unexpected situation	
	S63 Measures against omission of software requirements	
	S64 Necessity of prerequisite checks	
S7 Understandability of Requirements	S71 Rationality of the number of requirement commands etc.	
	S72 Meaning of independence	
	S73 Problems on understandability of the 50038 requirements	

S12: In some safety designs, approaches except for MWF, MNWF are effective.

- Some of the safety-critical functions do not lead to hazards even if the subject function becomes out of order. = They are not MWF or MNWF. (e.g.: monitoring functions)

A function with certain characteristics should take a MWF/MNWF approach.

It depends on the designer's plan which to choose MWF or MNWF.

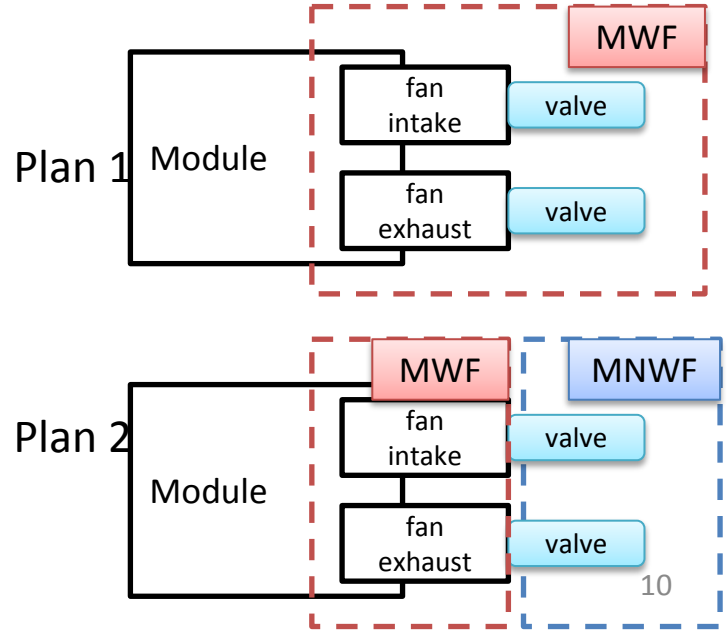


- MWF (redundancy) is effective.
- MNWF (works only at required time) is effective. ※Safe when the power is off.

It depends on the system conditions.

It varies with the view point which the subject function is regarded as MWF or MNWF.
•Module ventilation→MWF
•Valves→MNWF

e.g.: Scope of MWF and MNWF of air circulator



S21: Excessive Protective Design (1)

SSP50038 includes such items that require excessive protective designs. It results in the designs with an excessive number of prerequisite checks, commands and actions, then operability will lower.

What situation can be prevented by increasing commands? Double-check needs different points of view.

Prerequisite checks aim at issuing commands in the right conditions.

A: Requirements for an excessive protective design

Many prerequisite checks are packaged.

Commands are often rejected.

Respond to the command rejection

An excessive number of commands are packaged.

Operation becomes complicated.

B: Lower operability

Many actions are required.

Interface to check if the action is not mishandled is needed.

The order of issuing commands has something to make the operation complicated.

How should we prevent operation from getting complicated?

e.g.: What procedures avoid mishandling?

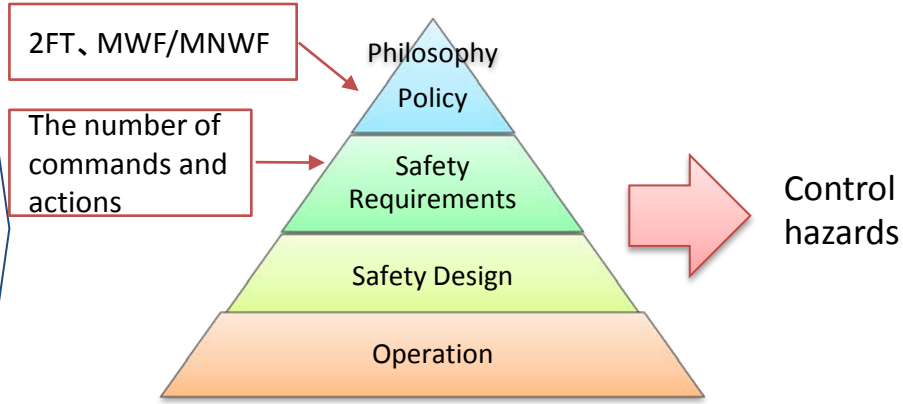
- Whole actions can be viewed.
- Feedback is done after an action.
- An action corresponds to an interface.

S71：Rationality of the Number of Required Commands etc.

There are questions about rationality of the number of commands, actions, and FT.

What foundation?

- Why are such number of commands required?
- Why are such number of actions required?
- Why are such number of FTs required?



- It is not the number of commands but the trigger event that is important.
  → When multiple commands are issued in one event, they become useless. Making multiple commands doesn't always "assure the commands delivery."
- To avoind mishandling, not only the number of actions but also such actions and interface that get people aware of mistakes are important.
  ※Taking the same number of commands in MWF and MNWF has raised operability.
  Matching the setting commands to cancelling commands helps to establish an easy-to-understand operation.
- Not only the 2FT but also easy system structures and hazard controlling methods with diversity are important.

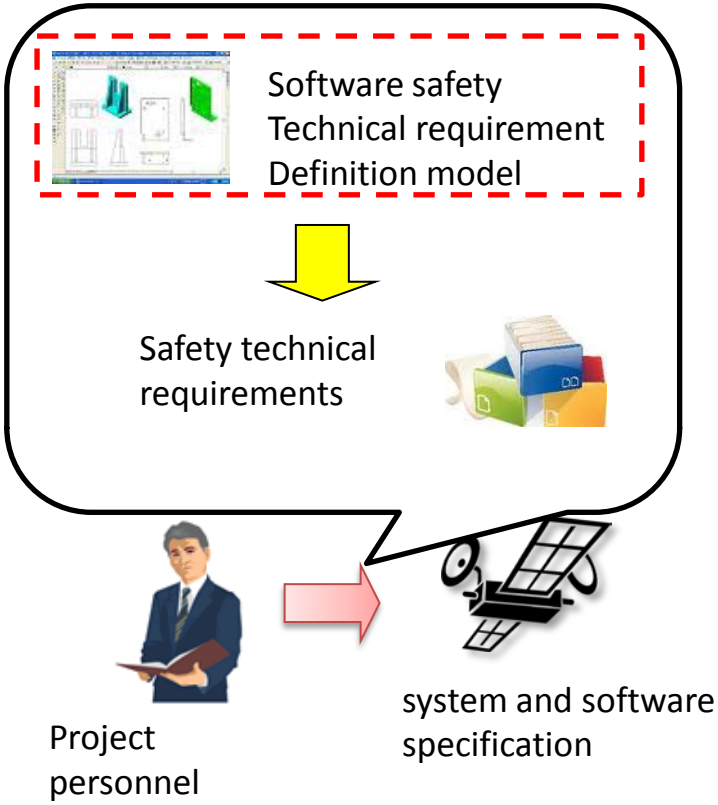
- To achieve the final goal of appropriate hazard controls, how should we work with safety policy, requirements, design and operation?
  e.g.: Is it appropriate to have 3 commands and actions respectively to secure the 2FT?

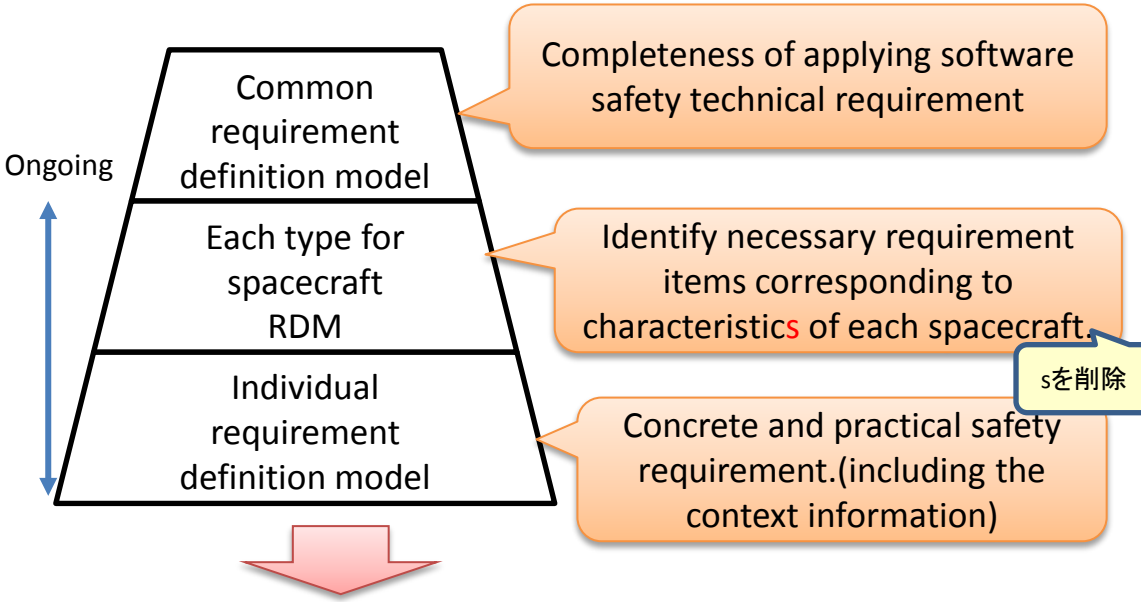
5: Analysis of safety requirement models

- Context(condition, hazard etc.) defines safety.
- Excess safety requirements result in not-safety.
- To realize "safety" requires wide aspects. e.g. system, software, failure etc…

→ Safety technical definition model has the characteristics of logical relation safety technical requirement item with its context.

ひとつの言葉ですか？区切り目がよく分かりません。

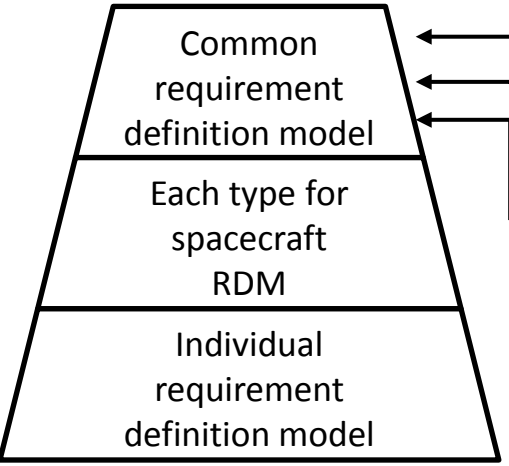




The model explains logically why each safety requirement is applicable.

5: Analysis of safety requirement models(2)

Structure of safety requirement definition model



C11

C12

C13

・Layer 1: common requirement definition model

◇ system model : The abstract models express system configuration item and function etc.(campus to express non-safety deployment model)

◇non-safety deployment model: straight define the relationship between off-nominal/failure and hazard in the system

◇safety requirement item category : the guide to control; non-safety deployment, adopt requirement items.

・Layer 2: Each type for spacecraft requirement definition model

To adapt a set of requirements by characteristics of spacecraft type(satellite, rocket etc.)
To offer the framework to define a set of concrete requirement items for Layer 3.

※To check each requirement items in layer 1 against practical safety design pattern.

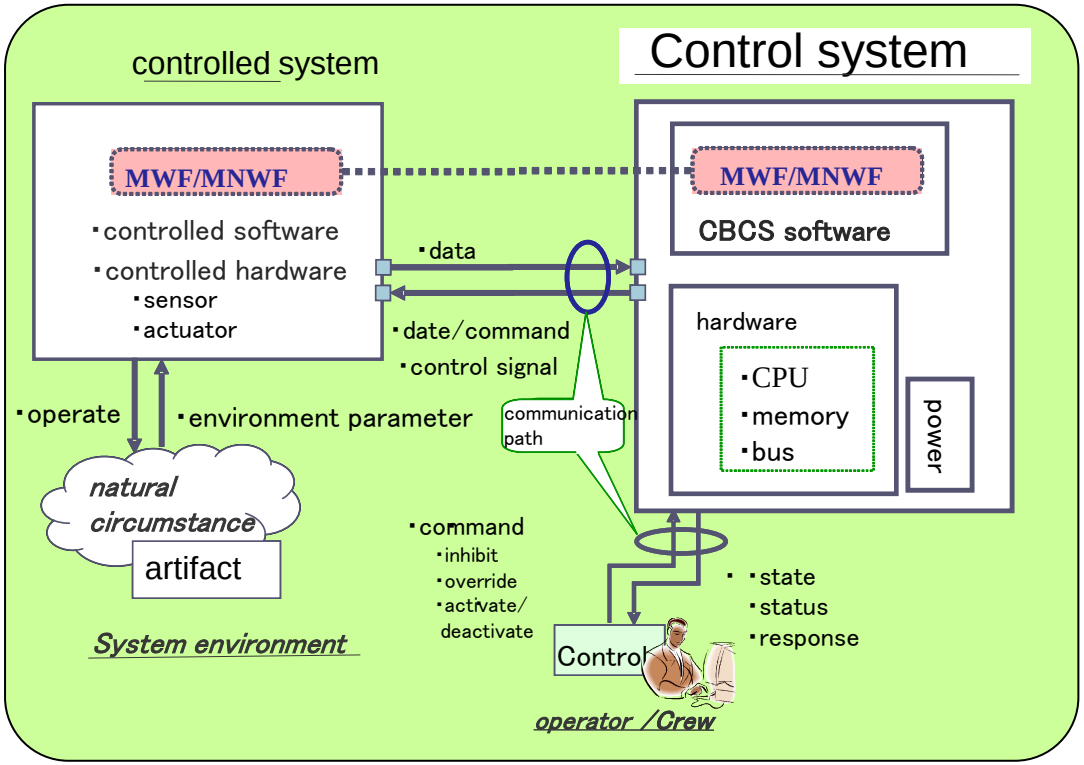
To Identify Improvement of CBCS safety requirement from the other industry safety criteria

・Layer 3 :individual requirement definition model

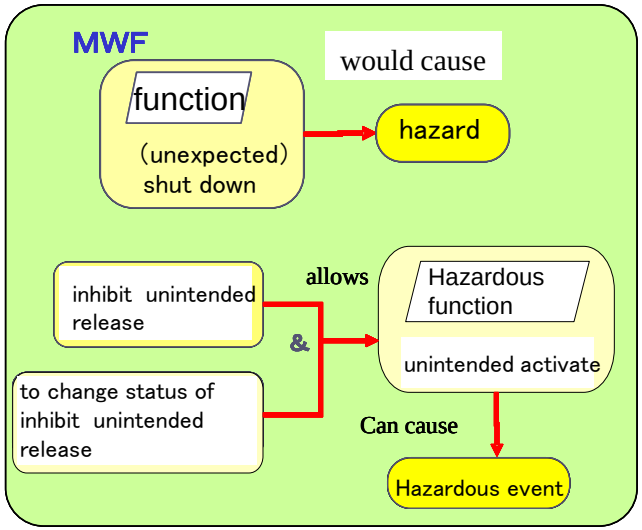
To define concrete requirement items for software about safety in each spacecraft projects. To choose appropriate requirement items by tailoring guide from the information in Layer 2.

5: Analysis of safety requirement models(3)

System model



Non-safety deployment model



Example: When hazard identifies collision, hazard control defines guidance control function.

- To identify system model by system model related points.
- To confirm whether the other hazard exists by non-safety deployment model.
- To identify the scope safety requirement items by safety requirement item category.

6. Conclusion and Future Work

We continue to consider and analyze these models by discussion with some professionals.

Finally, JAXA needs to define adequate safety requirements for each spacecraft software. At the same time, we must constitute the validation and verification method to confirm suitable requirements.

1. Analyze safety design pattern of spacecraft

   We research safety analysis and design of each function in detail to define what requirement is correctly adapted to space craft.

2. Discuss what is the new safety requirement that each space craft is adapted to.

   We focus on what is architecture and select function to define MWF/MNWF.

3. Complete the safety requirements definition model

   We will establish safety requirement corresponding to every space craft.

END