International Center for Quantum-field Measurement Systems for Studies of the Universe and Particles
WPI research center at KEK

Concept study support of research projects

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Abstract

Present status and plan of the concept study support of research are presented. We introduce CRDF (Concurrent Research Design Facility), which is derived from the concept study facility used in space missions. Furthermore, we have developed a CML checklist specifically for research, based on the CML framework used in space missions. With MBD and MBSE software tools, we are nearly prepared for the initial trial support. And we have already begun the initial trial support.

1. Introduction

The Goal of Systemology Support Section (S^3) is "To find best-practice engineering for researches for success".

The quality of a concept study is crucial as it determines the overall quality of the research. Therefore, we have the objective, "To improve concept studies of potential research projects at QUP by applying systems engineering approach optimized for research projects." We refer to this objective as "Concept study support of research projects."

In this paper we present the present status of preparation for the "concept study support" and the plan towards implementation.

2. SE approach for concept study of research projects

For space missions, systems-engineering approach plays the crucial role in early phases of the mission, specifically concept-study to project-formulation phases. We consider that there are lots of similarities in the concept studies of engineered systems and those for research projects. Therefore, by incorporating a systems engineering approach, we can likely enhance the concept studies of research projects.

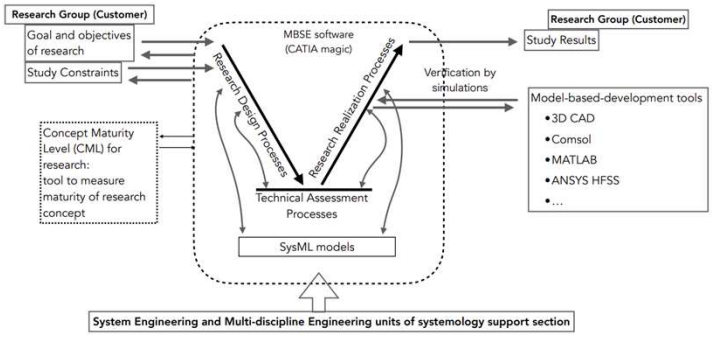

Figure 1. Concept of CRDF (Concurrent Research Design Facility)

Top: an overview of our support process. We will improve the maturity of the concept study according to the CML evaluation criteria and verify its feasibility using the MBD tools as necessary. And all those processes are managed using MBSE. Right: an example photo of a CRDF session. The facility is located in room 413 of building 4, KEK, Tsukuba.

3. Concurrent Research Design Facility (CRDF)

A concept study is considered complete when the scientific goals and objectives of the research are clearly translated into scientific investigations, and when the technical feasibility of the research is demonstrated at a manageable level. The Concurrent Design Facility (CDF) at the European Space Agency (ESA) and the X-team at NASA/JPL are well-known efficient facilities for achieving the aforementioned conceptual level. In these facilities, multidisciplinary experts come together concurrently within a predefined timeframe. We are taking a similar approach and referring to it as the "Concurrent Research Design Facility (CRDF)." Figure 1 illustrates the concept. In the CRDF, we utilize a Concept Maturity Level (CML) and a checklist to assess the maturity of the concept. If necessary, we provide support numerical simulation tools for Model-Based Development (MBD). We plan to adopt Model-Based Systems Engineering (MBSE) instead of Document-Based Systems Engineering, enabling the outputs and records of the support to be reused for future endeavors.

4. Present status

4.1 CML

The CML concept was first developed at NASA JPL in 2008. In 2013, they published their CML checklist. Later, in 2016, JAXA adopted the CML as criteria for assessing the readiness of mission concepts. In 2017, ISAS/JAXA defined its own CML checklist and began using it for the selection of space-science missions.

In this work, we defined the CML checklist for research based on the CML defined by ISAS/JAXA. We concluded that achieving CML3 is enough for research to show the science flow down and the technical feasibility. As a result, our CML check items contain up to CML3 and are 34 in 13 attributes. (Figure 2 & Table 1)

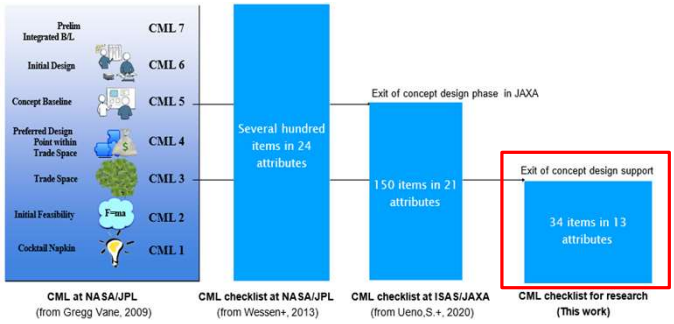

Figure 2. CML in space mission and for research

Gregg Vane 2009, Presentation to the Planetary Science Decadal Survey Steering Group
Wessen, R.R. et al. 2013, Proceedings of AIAA SPACE 2013 , DOI:10.2514/6.2013-5454
Ueno, S. et al. 2020, in Proc. SPIE 11450, DOI:10.1117/12.2560877

Table 1. CML checklist for research

Level	Science Objectives	Research architecture	Science data	Infrastructure	Instrument architecture	Instrument operation architecture	Technical Risk Management Plan	Technology development items	Technology Heritage	Environment protection	Schedule	WBS	Cost
1	Describe the goal of the research, namely, the key scientific question comprising the core of the research, in one sentence.	Describe in one sentence what will be acquired and how it will be acquired in order to approach the goal of the research.									A rough schedule for the entire research is shown.		
2	Describe the objectives of the research flown down from the goals of the research in a verifiable manner: what will be elucidated, and to what extent and how will it be pursued shall be described.	Clarify what is to be acquired (e.g., what is obtained from the experiments, observations, and analyses to be performed) and its requirements (value, quality, quantity, etc.). to achieve the scientific objective of the research.	The data, parameters, etc. to be obtained by the research (e.g., r in the case of CMB B mode research) should be clearly stated, and it should be clear why they are required by the scientific objectives of the research.	The infrastructure systems required to conduct experiments, observations, analyses, etc. shall be recognized and their performance requirements shall be listed in particular when special infrastructure is required.	Describe in one sentence the methods and techniques to realize the experiments, observations, analyses, etc. to be conducted to achieve the scientific objectives of the research.	Basic concept of operation of instruments to realize the experiments, observations, analyses, etc. to be conducted to achieve the scientific objectives of the research is defined.	Risks in obtaining science objectives of research are studied in respect to the performance of the investigations (experiments, observations, analyses), the technology, infrastructure, and operation of instruments to realize the investigation. The risk items are identified accordingly.	Identify key technologies of the investigations and items which require technology development.	When utilizing existing technology, clarify the development/project that is the basis of the heritage, the boundary conditions for the use of the existing technology in the project, and the implementation status of the project.	Identify whether there are requirements for environmental protection in the environment where the experiment/observation is conducted.	When it is necessary to acquire new research funds, opportunities to propose research funds are identified.		The scale of costs required for the research should be estimated by analogy, etc., based on past similar research.
		It should be shown that the scientific objectives can be achieved by the experiments, observations, analyses, etc. at the level of back-of-envelope calculations and estimates.		Provide comparisons to the research infrastructure of previous similar studies.	Compare the methods and technologies used in the experiments, observations, analyses, etc. conducted to achieve the scientific objectives of the research, with other technologies.								
		The environment required for the experiments, observations, analyses, etc. to be conducted to achieve the scientific objectives of the research should be recognized.											
3	Describe the investigations, i.e. experiments, observations, analyses, etc., conducted by the research. The investigations must achieve the objectives; however, the investigations might only make progress toward the goal without fully achieving it.	The possibility of conducting different experiments, observations, and analyses to achieve the scientific objectives should be explored, and the resources required, the risks of the research, and the significance of the results should be compared.	The possibility of acquiring different data, parameters, etc. to achieve the scientific objectives should be explored, and the resources required, the risks of the research, and the significance of the results should be compared.	The relationship between the size of the cost, risk, and programmatic challenges and the scientific value of the research should be quantified.	To consider other methods and techniques that can achieve the scientific objectives of the research with respect to the methods and techniques to realize the experiments, observations, analyses, etc. to be performed, and to understand the relationship between the achievement of the scientific objectives and the costs, risks, and programmatic issues.	Flow down from the science objectives of research to the basic concept of operation of the instrument is clearly defined.	Risks are compared for different research architectures, research infrastructures, and instrument operations.	Compare the key technologies and its development items among different investigations (experiments, observations, analyses).	When considering multiple methods and technologies with different costs, risks, and programmatic issues for experiments, observations, and analyses conducted to achieve the scientific objectives of the research, the limitations and risks of using existing technologies in each case, to clarify and compare the advantages.	Evaluate candidate implementation policies for environmental protection.	Evaluate the impact of changes in research schedules due to changes in the timing of research funding acquisition on scientific results, and the impact of changes in development schedules on the implementation period.	The work elements required to proceed with the research should be recognized hierarchically from the research as a whole.	Consider multiple methods and technologies with different costs, risks, and programmatic issues for experiments, observations, analyzes, etc. to achieve the scientific purpose of research, and organize the relationship between costs and scientific results obtained for each.
					An appropriate baseline of methods and techniques is established to realize experiments, observations, analyses, etc., based on the balance between the achievement of scientific objectives and cost, risk, and programmatic issues.	Different basic concepts of operation of instruments to realize the experiments, observations, analyses, etc. to be conducted to achieve the scientific objectives of the research are studied, and the relation between the science outcome and cost/risk/programmatic issues is quantitatively discussed.							

4.2 MBD and MBSE tools

The MBD software packages listed in Figure 1 are maintained in our section. We selected Magic Systems of Systems Architect, a commercially available software, as the tool for MBSE, since it allows direct integration of the SysML model with MBD software.

5. Schedule

We plan to establish the environment for CRDF and start a trial of concept study support of research within this fiscal year (Figure 3). We have identified two candidate research projects for the trial. Trials have already begun for one research project. Additionally, we will conduct iterative trials and optimize the support process.

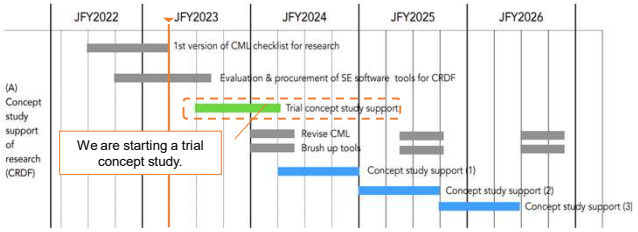

Figure 3. Mid-term schedule

6. Conclusion

To implement the concept study support of research which is one of the objectives of the systemology support section, we defined CRDF. We have established CML check list for research as one of the tool of CRDF. MBD and MBSE software tools are also being implemented. We have already begun the first trial support.