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An application of the Design Structure Matrix to Integrated Concurrent Engineering

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ABSTRACT

This paper demonstrates an application of the Design Structure Matrix (DSM) to Integrated Concurrent Engineering (ICE), an approach to conceptual space systems design intended to increase the pace of work by bringing together all relevant personnel in the same room to conduct focused, collaborative one-week design studies. Although the DSM methodology explicitly incorporates the concurrent aspects of engineering design, it has not been applied formally to an integrated, rapid design environment such as ICE. In this paper, a DSM consisting of 172 design parameters and 682 dependencies is constructed to represent the typical process employed at the Mission Design Laboratory (MDL), an ICE facility at NASA Goddard Space Flight Center (GSFC). Analysis of the DSM reveals an optimal sequencing among five phases of the ICE design process, the interdependent disciplines in the design team, and a set of starting assumptions that can be made at the outset of the work to facilitate a more structured approach to the highly complex and iterative process of space systems design.

1. Introduction

In recent years, NASA, ESA, and the private sector have begun to implement an innovative approach to space systems design. This new practice, known as Integrated Concurrent Engineering (ICE), increases the pace of conceptual design by bringing together all relevant personnel to conduct focused, collaborative one-week design studies. In contrast to traditional "over the wall" engineering [1], the ICE environment is meant to explicitly remove the physical and organizational boundaries to communication so that design tasks that once took months or even years to accomplish can be completed in a matter of days [2,3]. As the name implies, these design settings are not only venues for concurrent (as opposed to sequential) engineering, but they also are integrated in the sense that the various discipline engineers (usually one per discipline) are collocated in the same room so that they are able to concentrate their efforts on the truly interdisciplinary aspects of the design.

The ICE design center under study in this research is the Mission Design Laboratory (MDL) at NASA Goddard Space Flight Center (GSFC). In this setting, a team of approximately 20 engineers produces a full conceptual design for a spacecraft and surrounding mission architecture over the course of a five-day period. Typically, an MDL mission concept involves a single spacecraft in Earth orbit carrying either Earth or space science instruments. Recently, though, the MDL has conducted an increasing number of design sessions focused on less familiar topics such as planetary missions, multiple-spacecraft architectures, and various advanced concepts.

The MDL design team generally includes a Team Lead, a Systems Engineer, and 16 discipline engineers: Attitude Control, Avionics, Communications, Electrical Power, Flight Dynamics, Flight Software, Integration and Test, Launch Vehicles, Mechanical, Mission Operations, Orbital Debris,

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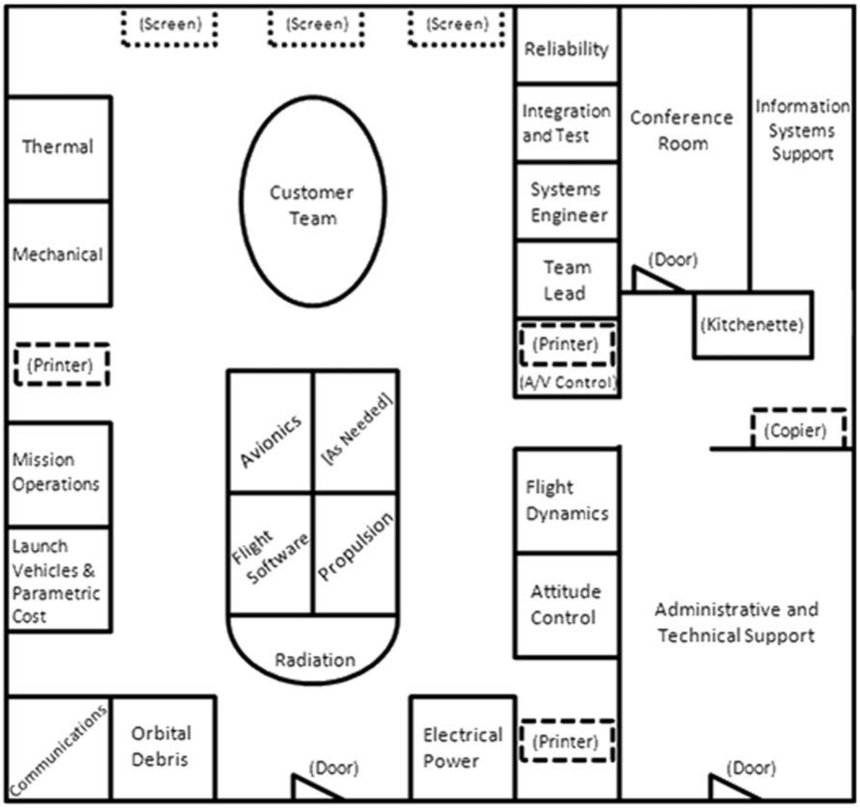

Fig. 1. Layout of the NASA GSFC Mission Design Laboratory. The main lab holds work stations for all of the discipline engineers, a table for the customer team, and a full audio-visual system.

Parametric Cost,[1] Propulsion, Radiation, Reliability, and Thermal. In general, each discipline is represented by one expert engineer, but two or more engineers are sometimes assigned to disciplines that are expected to be particularly important for a given session. The facility contains approximately 20 work stations, each of which maps to one of the subsystems/disciplines involved. In addition, the customer team sits at a conference table in front of the room and is actively involved throughout the course of the session. The layout of the MDL facility, including the location of each discipline's work station, is shown in Fig. 1.

The purpose of this paper is to identify and explore the interdisciplinary problems in the ICE environment using a system-wide representation of the entire space systems design process. The structure of the paper is as follows. First, a systems-level representation technique called the Design Structure Matrix (DSM) is introduced, and its applicability to the ICE environment is explained. Then, the DSM is used to reveal the phases of the ICE design life cycle. A more detailed analysis of the most tightly coupled aspects of the work is then used to determine the interdependence among disciplines in the design team. Next, a method for further optimizing the design process by making certain starting assumptions at the outset of the work is described. Finally, some conclusions about space systems design in the ICE environment are offered, and the next steps in the research are discussed.

2. Overview of the Design Structure Matrix

The Design Structure Matrix is a means of representing an entire system, product, or process by aggregating individual interactions among components, people, activities, or parameters [4]. The DSM is essentially an N^2 diagram that is structured in such a way as to facilitate systems-level analysis and process improvement. By convention, a mark in cell *i,j* of the matrix indicates that the item in row *i* requires information from the item in column *j* as an input.

The DSM is similar to some other project management tools but improves on their capabilities in several important ways. For example, the Structured Analysis and Design Technique (SADT) is used to represent the same type of information flow as the DSM, but it uses a flow-graph representation that can quickly become as complex as the process that it models. Thus, SADT provides little more than descriptive capacity with limited potential for process improvement [5]. The House of Quality used in the technique Quality Function Deployment (QFD), on the other hand, uses a more manageable matrix-based format. Although the primary use of QFD is to map system requirements to product features, the "roof" of the House of Quality provides a DSM-like representation of dependencies [4]. Unlike the DSM, it

[1] Although Launch Vehicles and Parametric Cost are unrelated disciplines, the same team member serves in both roles in the MDL.