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Design Structure Method As Applied To The Structural Organization Of A 5th Genertation Fighter Jet

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ABSTRACT

In current times, the demand for protection against enemies in a volatile geopolitical climate is an increasingly demanding concern. Many countries invest billions of dollars attempting to protect their borders and in fact strive to become the most powerful and dominant war power in the world. As the dollar amount of each country increases, and while other countries seem to always beat each other, the path for innovations and demand is never ending. The complexity of each project continues to grow as they become very sophisticated in their respective field.

In recent decades, it's been proven that whoever reaches the highest limit in the sky and has a "bird's eye" view on everything seems to be the best; air superiority is paramount. This aspect seems to be every defense contractor's ambition and goal when designing new air war machines. At present time, there are very few companies attempting and succeeding in building such air vehicles. However, the skill level and intellectuality is by no means at risk or deficient. There are many bright minds willing and prepared to developed tomorrow's protection.

Where many companies and programs fall is successfully sustaining the skill talent throughout the life of the program. Although aeronautical companies have put much thought and work into this, there is still a lack of definition and/or verdict to truly eradicate the problem. The fact of the matter is that predicting future program outcomes or following legacy programs is not sufficient anymore. New programs must individually be conceptualized and analyzed to better maintain the organizational structure throughout its life cycle.

This research presents a logical method which can be utilized by companies to better structure program organizations. It presents an example utilizing real data from a fortune 500 aeronautical company. Results of the study presented is an analysis using design structure matrices

from observed data over the last four years. This research would help aeronautic companies to address their internal organizational structure issues.

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CHAPTER 1: INTRODUCTION

1.1 GENERAL

This work presents an effort to model, analyze, and improve upon the current organizational layout structure on a fifth generation fighter jet, using Control Surfaces (here on after referred to as CS&E) as a reference point. Most aeronautics engineering design companies face this problem within their organization structure. Although there have been efforts to initiate internal structural improvements, serious issues remain. This work presents (1) a mapping structure to reveal the current implementation of organization structure used, (2)followed by a Design Structure Method analysis that will predict the type of future organizational structure that would generate a better outcome. By knowing the best organizational structure within an engineering team, specifically for control surfaces, talent can be allocated accordingly. The study was performed with data from a Fortune 500 aeronautics company, thereby utilizing, sufficient quality figures of the existing configuration.

1.2 PROBLEM STATEMENTAND RATIONALE

For many years, efforts to improve a program's/project's organizational arrangement have been exhausted. Most efforts have revolved among "organizational re- structure" where programs lay away many of their superfluous talent, and keep those who are still "useful". This provokes reactionary resistance from many professionals whom were promised career security.

The issue is that many of the efforts usually follow a "demand" forecast, where hiring many professionals when needed may affect them negatively in the long run. When the program is at its inception, many designers and analysts are hired, the program progresses, where does all this talent go? Most of the time they must move companies and/or are laid off. A balance must be found

where early talent can then be used at later stages of the program/project. Similarly, this can be applied to one of the most vital components of an air vehicle – control surfaces.

Current methodology for a control and surfaces team adheres to isolated matrix model, i.e., one team for the entire air vehicle. Information transfer is key is a system of such large complexity. CS&E interacts with the entire warplane, impacting all other systems and sub systems, both internally, and externally. So why is it that the CS&E team would be isolated and established as an independent team under air vehicle engineering? This formula is costing companies millions of dollars without rendering a solution.

1.3 OBJECTIVE

In today's economy companies are constantly seeking to maximize resources in order to boost productivity and reduce costs. Accordingly, the objective of this study is to develop an efficient method to classify the deficiencies in contemporary corporate organizational structures within pertaining to the construction of fifth generation fighter jets – with an emphasis on control surfaces. Concomitantly, this research developsa design structure matrix to render an improved organizational model for control surfaces on a fifth generation fighter jet. The idea behind this concept is that once the predictive model is able to identify improvements within the organizational layout, some elimination plans can be put in place. By using the existing knowledge,it is intended to evolve the current environment. The predictive model would be based on existing channels, links, relationships, processes, actions, data transfer, and communication features currently used. As in any other organizational technique, the ultimate goal is necessarily to ascertain a more cost–efficient production model. This research will be appliedto the target field through a matrix example.

1.4 CONTRIBUTION

As contribution, this work presents a unique approach to predict project's future organizational structures, and how to pro-actively prepare for the change throughout the project's life cycle.

Although many aeronautical companies and large fortune 500 companies have put tremendous efforts onto this problem, this is an attempt to improve one of the most vital components on an air vehicle – control surfaces. Most approaches using Design Structure Methods to improve an organizational structure focus on hierarchal decomposition but not pro-activeness and longevity of the project. The outcome has a practical application in the aeronautical industry and any other field with similar structure. In addition, this work will be able to be implemented in a more realistic industrial scenario such as the aerospace field, due to the fact of using real time data and methods.

Certainly, the attained method is an advantageous tool that can be used by designers, manufacturing and industrial engineers, planners, managers, and anybody involved in organizational architecture.

1.5 THESIS OUTLINE

The completion of this paper is divided into five sections. The entire document discusses the topic of Design Structure Methods utilized to optimize structural organization within an aeronautical Fortune 500 company.

Chapter 1 "Introduction" presents a general idea and description to the audience about the target trying to be reached. It further explains the general idea, problem, objective, and contribution

Chapter 2 "Literature Review" defines what DSM is and some of its functions, followed by a description of generation fighter jets,

Chapter 3 “Methodology” shows the current method used in industry, what has been attempted, and two examples that have been successful in industry using DSM.

Chapter 4 “Case Study” exhibits how the proposed DSM theory applied to a real case scenario.

Chapter 5 “ Conclusion” encapsulates the theory and aspiration of this paper, and also presents prospective aspects where the findings can prolong.

CHAPTER 2: LITERATURE REVIEW

2.1 DESIGN STRUCTURE METHOD

A significant impact has been noted since the turn of the twentieth century. With the inception of the industrial revolution, came the illusion of “more is better”. As modern

innovations inundate the human mind with new information, it becomes harder to effectively share skills and ideas with others; when it comes to getting the right information to the right place at the right time, the potential for error escalates. [1]. Hence, a technique must be developed for mastering the vast amounts of information required to master engineering process - Design Structure Method is one such technique.

Design Structure Methodas defined by Browning is a network-modeling tool used to represent the elements comprising a system and their interactions – system's architecture and / or design structure [1]. Similar to design structure methods, a Dependency Structure Matrix by definition is an adjacency matrix of a graph where each entry *dij*represents the degree of dependency between node *I* and node *j* where each node stands for an element or variable in a complex system [2]. The larger the *dij*is, the higher the dependency is between node*i*and node *j*. DSM entries *dij*can be real numbers or integers. In this paper we focus on the binary domain, where *dij*=0 means that there is no dependency between node *i*and node *j*, and *dij*=1 means that node *i*and node *j* are dependent[2]. DSM construction involves detecting dependencies between the problem variables. Several methods are introduced in the literature for calculating pair-wise dependencies and constructing DSM [3]. The goal of DSM clustering is to find particular subsets of DSM elements (i.e., clusters) such that variables within a cluster are maximally interacting and variables within different clusters are minimally interacting.

DSM can aid is a variety of ways such as the following:

- Links
- Tasks
- Relationships

- Mapping (mapping dependencies)
- Clustering
- Actions
- Processes

The design and development of complex engineering products require the efforts and collaboration of hundreds of participants from diverse backgrounds. Many of the traditional project management tools (PERT, Gantt and CPM methods) do not adequately address problems stemming from such interpersonal complexities. While these tools allow the modeling of sequential and parallel processes, they fail to address interdependency (feedback and iteration), which is common in complex product development (PD) projects[4]. A matrix-based tool called the Design Structure Matrix (DSM) can be utilized to address this issue. This method differs from traditional project-management tools because it focuses on representing information flows rather than work flows. The DSM method is an information exchange model that allows for the representation of complex task (or team) relationships in order to determine a sensible sequence (or grouping) for the tasks (or teams) being modeled. [4]

Historical design approaches include the following;

- Design Spiral Method – simply begin from an idea and develop some type of conceptual design that can be taken to prototype or perhaps even production. The idea is constructed from prior knowledge, data being analyzed, or previous experiences and / or designs. This is the sequentially modified and analyzed until a better (optimized) solution is found [4]. Somewhat of a trial and error method approach which is what many of engineers are used to executing by testing. Benefits to this design approach is that it does speed up the process of bringing and idea to concept and production, however, this can also lead to

costly, over runs, and dangerous. This is due to the fact that it may force one to re design the entire system / product instead of just individual components

- Synthesis Model based Design Optimization – utilizing an algorithm to improve and optimize upon what has already been created. A downfall of this approach is that it demands for a product or design to have been initialized and verified – based on response set methods [4].
- Set Based Design – progressively shrink an initially large design space, executed through a much know process of elimination rubric. The process of elimination narrows down what has been affected versus what has not. Narrows down to particular actions, steps, materials, and / or components that ultimately renders the best results. [4]

With Design Structure Methodsthe three before mentioned classical design approaches are combined into a structured matrix so that it benefits users and designers in the long run.Fundamental DSM was initially introduced in the use of floor shop management in industrial production. In its early years, DSM offered floor shop based products an innovative solution to machine grouping. The method improved production cycle times and rendered an efficacious line to be followed for many years.

DSM applications include five categories:

1) Decompose
2) Identify
3) Analyze

4) Display

5) Improve

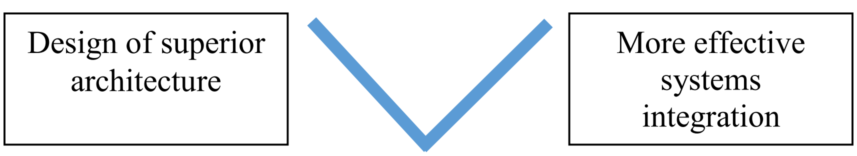
DSM classifications / categories:

1) Static architecture
2) Temporal flow models
3) Multi-domain matrix

Developing architecture involves:

1) Hierarchal decomposition (from product onto modules / components)
    a. Product break down
2) Assignment if functions to the modules and components
3) Interaction between modules and components (DSM)

Within the Systems Engineering “V” DSM emphasizes 2 in sectors:



Organizational product architecture DSM models

- Way people work together to deliver value
- OBS – organizational work breakdown structure

In DSM exists the utilization of two categories:

- 1 Dimension: utilized for sequencing, concurrency, and / or schedule
    - Number of rows equals the number of columns 1:1 ratio
    - Activities to tasks

- Triangular algorithm can be used

- 2 Dimension: mostly used for clustering
  - Number of rows and columns does not equal one another
  - Mutually exclusive
  - CI – Cluster Identification algorithm can be used

	A	B	C	D
A	A			
B		B		X
C			C	
D	X	X		D

Figure 1 - DSM Example

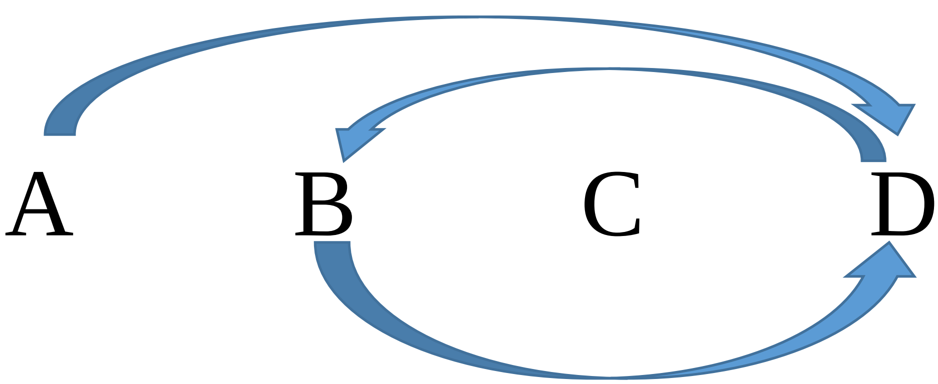


Figure 2– Communication of DSM Example

2.2 GENERATION FIGHTER JETS

In the aviation industry, the term "'generation" is used to classify fighter jets from an approximate point in time to another. The time span can represent design concepts and/or production time.

War and technology go hand-in-hand. Yet, technology evolves, and, as a consequence, arms markets change. It would be wise to avoid being unduly swayed by current market forces in contemplating their next fighter purchase. In the near future, the U.S. will be joined, first by Russia, and then by China. The following sub section render a description of all fighter jet generations[5].

2.2.1 FIRST GENERATION FIGHTER JETS

This category comprised the earliest jet fighters. Classic cases were Germany's Me 262 and Britain's Meteor, both of which entered service in 1944 toward the end of World War II, and the US F-80, which came along the next year. The hallmark of the Gen 1 fighter was its revolutionary advance in speed over its piston-engine predecessors [5].

2.2.2 SECOND GENERATION FIGHTER JETS

Second generation fighters starred in the Korean War. Most notable were the USAF F-86 and the Soviet MiG-15. According to Walter J. Boyne, writing in Lockheed Martin's Code One magazine, this generation "sought to maximize fighter performance by tailoring the airframe to the potential of the jet engine." Example: the use of highly swept wings [5].

2.2.3 THIRD GENERATION FIGHTER JETS

State of the art in the late 1950s and early 1960s, fighters of the third generation included USAF's "Century Series" fighters—F-100, F-101, F-102, F-104, F-105, F-106—and the Soviet MiG-17 and MiG-21. They featured advanced missiles, supersonic speed, and more-sophisticated engines. The F-4 Phantom was a late Gen 3 fighter, and perhaps iconic of the group due to its numerous and record number of sales around the world. The F-4 Phantom is still being used by several countries in South America and the Middle East [5].

2.2.4 FOURTH GENERATION FIGHTER JETS

These fighters debuted in the mid-1970s and are still tops in most of the world. This group includes USAF's F- 15 and F-16 and Russia's Su-27 and MiG-29 (and offshoots). Weapons, engines, and avionics put earlier aircraft to shame. Thirty years of improvements have pushed some fighters into a group known as "Generation 4.5." These include the latest F-15s and F-16s for overseas customers, and the MiG-35, Su-30, and Eurofighter Typhoon [5].

2.2.4.1 4.5 GENERATION FIGHTER JETS

A 4.5 generation fighter jet can also be somewhat classified by taking an already existing fourth generation fighter jet, from the 1900 and beyond, and dramatically enhancing the capabilities. Such capabilities consist of integrated avionics, suites, advanced weapons, replacing turbine blades, radar absorbent materials, and high capacity data inks. The purpose for these upgrades is due to the high demand of homeland security measures. As radar systems along with ground to air missiles evolved, fourth generation fighter jets became vulnerable to such threats. 4.5 generation alieved some of the challenges and burden, and aided in controlling the gap between their newer counter parts, fifth generation fighter jets, and the legacy fourth generation fighter jets.

It was also a much economical approach for governments and department of defense to invest in upgrades to already existing aircraft than to invest in entirely new programs [6].

2.2.5 FIFTH GENERATION FIGHTER JETS

A fifth generation fighter jet is perhaps the most talked about now a days and also one of the most important weapons for a country to own. The class is defined by all-aspect stealth, internal carriage of precision weapons, active electronically scanned array (AESA) radars, and “plug and play” electronics. At present time there is only one member to this family and it is the American F-22 Raptor made by Lockheed Martin. The F-35 Lightning II has recently join the club as of July of 2015, by declaring its first four marine F-35s operational capable. [5]

- Stealth
- high maneuverability
- advanced avionics
- networked data fusion from sensors and avionics
- Multiple roles.

2.2.5.1 STEALTH

The F-35’s low radar cross-section and radar-absorbent surface coatings make it more difficult to detect by radar, but they do not make it invisible. In any case, detection by radar matters less and less because by switching on its radar a fighter becomes as visible as someone turning on a flashlight in a dark room. Therefore, the preferred detection sensors are optical, like Infra-Red Scan and Track (IRST), and in this case the large and very hot exhaust plume of the F-35’s 45,000-lb thrust engine is as visible as a blowtorch in the same dark room [5]. Stealth, in any case, is a relative concept, and depends on many variables. In addition, since the first “stealth” aircraft, the

F-117, entered service almost 30 years ago, this is hardly a revolutionary capability. Nevertheless, it is, as it and other stealth aircraft have shown a maintenance nightmare of extraordinary proportions. Furthermore, the F-35 will only be stealthy if it carries nothing under its wings. This means no pylons, so no gun (except for the F-35A, which has an internal gun); no extra fuel tanks; and no large weapons, as the small dimensions of its two bomb bays allow internal carriage of only two Amraam missiles and two JDAM guided bombs [5]. That is not an impressive weapon load for an aircraft that, as Gen. Miller noted above, is intended to penetrate ever-more formidable "growing anti-access, area-denial capabilities" in hostile territory. A final word on the F-35's stealth: its design makes it less detectable by radar in its frontal sector, but not from the side, nor from the rear, where the laws of physics dictate it will be easier to detect than face-on[5].

2.2.5.2 HIGH MANEUVERABILTY

Contrary to some existing aircraft, the F-35 has no special maneuverability-enhancing design features such as canard forward surfaces, vectoring nozzles or "supercruise" capabilities that exist on other fighters already in service [5]. Its thrust-to-weight ratio is limited and unlikely to improve since the F135 engine has limited growth potential. Two decades ago, the Sukhoi Su-27 unveiled its celebrated "cobra" maneuver, demonstrating a degree of agility that until then had only been dreamed of. But, again, maneuverability is something of a decoy: in modern and future combat, when aircraft are detected and engaged at ranges of over 100 km, whether a fighter is highly maneuverable or not is likely to matter far less than the performance of its sensors or the range and effectiveness of its weapons [5].

2.2.5.3 ADVANCED AVIONICS

Full sensor fusion and networking capability already exist, and was notably demonstrated in combat by French Rafales and Royal Air Force Typhoons during the 2011 operations in Libya. The F-35 will deliver this capability at the turn of the decade, if all goes well, so it is hardly revolutionary. The F-35 is equipped with the APG-81 electronically-scanned radar, but this technology is already being retrofitted to previous-generation US fighters like the F-15E (APG-82(V)1 and the F-18E Super Hornet (APG-79); it is also available in pod form (AN/ASQ-236), has been exported to US allies, and is produced or in development by non-US manufacturers like Selex Galileo, Cassidian and Saab[5].AESA radars also are being retrofitted to the DassaultRafale and, if the partner nations can agree, will be to the Eurofighter Typhoon. An AESA radar is planned for the future Saab Gripen E/F (also known as Gripen NG), so this will be a run-of-the-mill technology by the time the F-35 finally enters service. The F-35's networking capabilities are likely to exceed anything that is available today, but the improvement will be a matter of degree, not of nature, because today's combat aircraft are already networked through the Link 16 datalink, which is already in service and being retrofitted to many NATO and allied fighters[5].The F-35 also features an innovative Distributed Aperture System (DAS), which consists of sensors mounted around the aircraft that will provide the pilot with a 360-degree, spherical view of his surroundings. That is a very significant technical advance, and will no doubt prove a real plus for the pilot because it will provide unmatched situational awareness – if it works as advertised, however, and if its data is presented in a way the pilot can assimilate and use[5].The pilot's Helmet-Mounted Display System (HMDS) was designed to do this, but it stubbornly refuses to work despite a decade of design and testing. The Pentagon's Quick-Look Review (QLR), leaked late last year, rated the HMDS a "program-level high development risk" because

faulty displays, night vision and image jitters, and latency issues plague it: in short, it is not fit for purpose. Indeed, the QLR noted that it is less functional than legacy (previous-generation) equipment, adding that no satisfactory corrective has action has yet been identified[5].So dire is the situation, in fact, that Lockheed has asked BAE Systems to adapt its existing Eurofighter helmet display as an interim solution. This leads to a much bigger problem: since the HMDS was going to provide all the information that the pilot would ever need, no Head-Up Display was fitted to the F-35. So if whatever helmet display is finally selected cannot provide the same functionalities as HMDS, F-35 pilots will end up having inferior, "old-generation" situational awareness, which is somewhat ironical given what the F-35 promised [5].This would not be acceptable, so the only fix is a redesign of the entire systems architecture, which at this stage is too complex, too time-consuming and too expensive to seriously consider. However, a fix may be in the works. Vice Adm. David Venlet, the F-35 program manager, said May 8 that a fix being worked on may solve the HMDS' jitter picture and lag time issues. "I am focused on seeing the demonstration of those fixes working and being effective…That will be paced out through the remainder of this year and into 2013" [5]. Other F-35 "innovations" such as IRST, passive sensors and integrated countermeasures are already operational on Rafale (SPECTRA suite), Typhoon (DASS); they are planned for Gripen NG and are also being developed for retrofit to older US fighters, like the IRST sensors for the US Navy's Block II Super Hornet, which will carry it recessed into the front of a fuel tank [5].

2.2.5.4 DATA FUSION

Again, the idea of fusing data from all on-board sensors is nothing new, as it has been operational for several years on the latest European fighters, Rafale and Typhoon, and will be operational on the Gripen NG if that variant ever reaches service. French Rafales, for example, use

their MICA missiles as additional sensors, and combine their data with that provided by their SPECTRA self-protection suite, radar, IRST, other onboard sensors and data received from other friendly aircraft, AWACS, or ground control centers to present a single, unified and constantly updated tactical picture to the pilot. And it's becoming ever more banal, as evidenced by the ongoing effort by Boeing and the Naval Air Warfare Center to add a networking capability to the Distributed Targeting System which will soon be operational on the Super Hornet. If, in a decade, the F-35 enters service with a modern data fusion capability, any improvement in terms of data fusion will be a matter of degree, not of nature [5].

2.2.5.5 MULTIROLE CAPABILITY

There is no modern combat aircraft that doesn't claim to be capable of carrying out multiple roles, but even legacy US fighters routinely carry out widely diverse missions: F-15C interceptor and F-15E multirole/strike; F-18E Super Hornet (Air-to-air; strike/attack and electronic attack), and of course the F-16, whose latest versions are far more capable strike aircraft than the lightweight interceptor it was initially designed to be[5].The "omnirole" Rafale has, or will, replace seven models of previous-generation aircraft used by the French air force and naval aviation for interception, ground attack, nuclear and conventional strike, and reconnaissance missions; it also has a naval variant. The "swing-role" Eurofighter Typhoon is capable of interception and ground attack missions, and is to gain conventional strike capabilities with stand-off missiles, although these are more limited [5] .As the only Swedish air force combat aircraft, the original Saab JAS-35 Gripen developed since the 1980s was from the very beginning tasked with interception, ground attack, strike, reconnaissance and naval missions, including anti-ship. In fact, JAS is the Swedish acronym for Fighter / Attack / Reconnaissance, so multirole capabilities have been in service for decades. So, again, there is nothing revolutionary in the capabilities the

F-35 will bring to the party - a decade from now, if all goes well, and at a cost of over $400 billion. But there are considerable limitations to the F-35's own vaunted multirole capabilities. To remain stealthy, it can carry only internal weapons (two bombs and two air-to-missiles), which severely limits its combat firepower. Its internal weapon load, at 4,000 lbs., is inferior to that of the F-117 Nighthawk, which could carry 5,000 lbs. of assorted internal stores in its internal bomb bays, so in this respect the F-35 is less capable than its stealth predecessor [5].

2.2.5.6 INTEROPERABILITY

The governments of several F-35 partner countries, including Canada, have tried to justify their choice by claiming that they need the F-35 to be able to operate with the United States as part of future coalitions. This is another nonsensical claim that has only gained traction because of the incompetence of politicians and the gullibility of their electorates. In just the past decade, the US and their allies have carried out joint air operations in the former Yugoslavia, during both Iraq wars, in Kosovo, in Afghanistan, and most recently against Libya, while operating very different kinds of aircraft [5]. In fact, there is no need to fly the same aircraft: The only real requirement for joint operations is that participants be able to talk to each other and to exchange data, and this they have been able to do for decades. It is also desirable that staffs and pilots have previous experience of working together, and this is one thing that NATO does very well, and that bilateral exercises and bigger events like Red Flag routinely provide [5]. Also desirable, but lower down the scale, is that aircraft be able to refuel and rearm on allied air bases, and again this is already possible in the case of all NATO members (who use ground equipment to common standards) and the many allied countries who use European, French or US-made aircraft. Even Russia uses NATO-standard ground equipment, as French officials discovered to their surprise back in the late 1970s, when a squadron of MiG-23s visited the French air force's famous Normandie-Niemen squadron at Reims

air base, and were able to refuel and turn around using the base's ground equipment [5].The inanity of the F-35's interoperability claims was clearly stated by NATO's supreme allied commander transformation, Gen. Stephane Abrial, a former fighter pilot and chief of staff of the French air force, when he testified before the Canadian House of Commons Defence Committee on May 3. According to a May 4 report published by Canada's Postmedia news, Abrial told the committee that *"We do not advocate a single type of aircraft, single type of ships, single type of rifles….We never wanted to make sure everyone has the same equipment: that's not our goal." Abrial said interoperability has to do primarily with training and ensuring all NATO forces have sufficient skills to function as one on the battlefield"* [7].

2.3 CONTROL SURFACES

As with any system thatis propelled under its own power, there must also be a sub system that is able to control the amount, direction, and placement of such power. In one's daily life this can be related to the accelerator and steering wheel in a car. The accelerator controls that amount of oxygen-letthrough the throttle body and into the engine's cylinder chamber. This step gives the user the ability to control acceleration and speed of the car. On the other hand, the steering wheel gives the user the capability to control the direction of the engines power by turning the wheels right of left. So how can one control a system that is in flight, up to 80,000 feet in the air, one may ask. How is it able to turn left or right and accelerate if it is not touching the ground? This is where a jet's control surfaces and edges come into play.

A control surface in essence is exactly as the word itself states; it is s surface along and/or attached to the jet's body, that controls the jet's direction, stabilization, and position in flight. These surfaces are what stresses the airplane in flight and allow it to land, take flight, and turn.
There are three angles that must be controlled in an airplane; pitch, yaw, and roll.

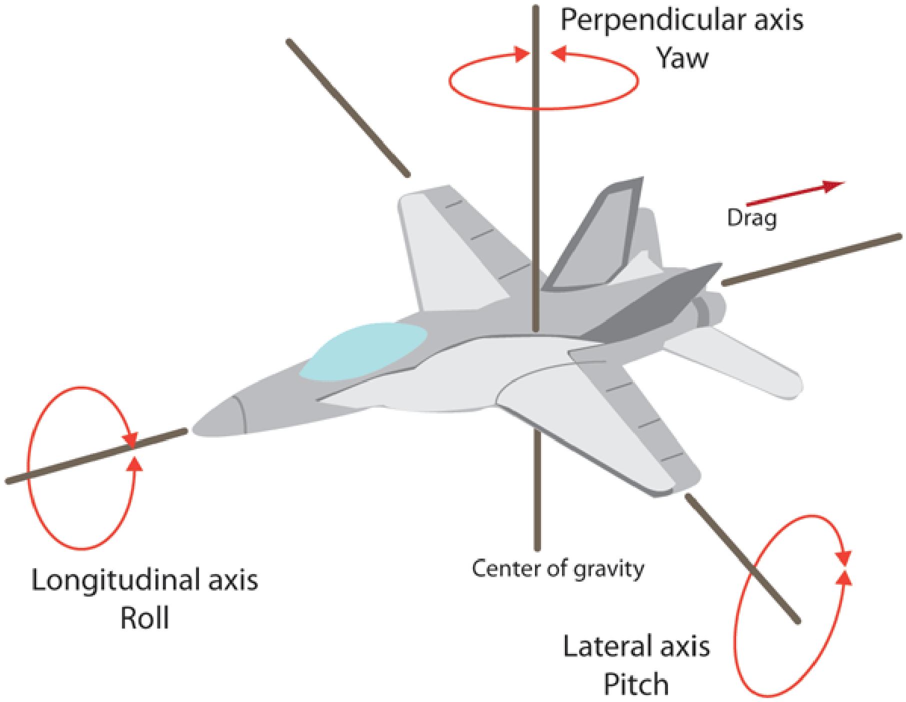


Figure 3 - Three Angles of an Aircraft in Flight

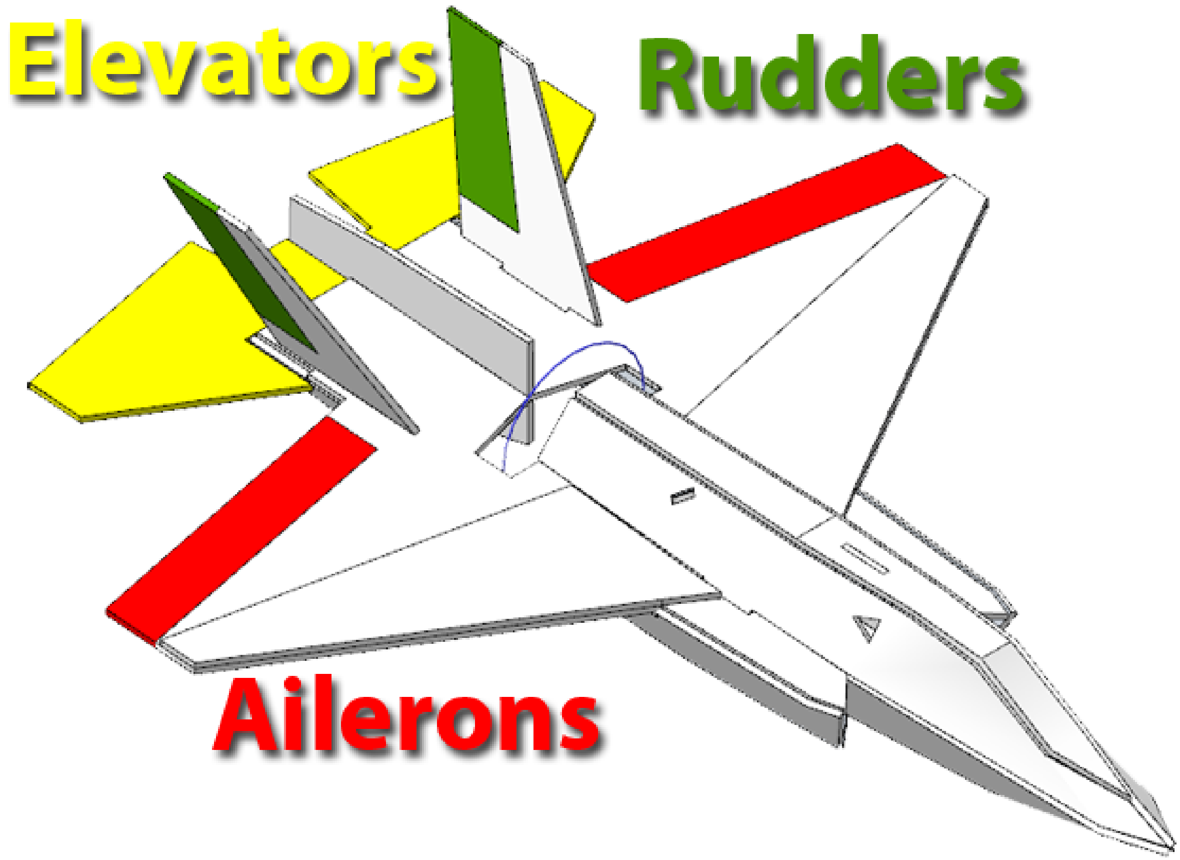


Figure 4 - CS&E on a Fighter Jet Movement

Control Surfaces are comprised of the leading and trailing edge flaps, horizontal tails, and vertical tails. The leading and trailing edges allow the aircraft to move along the perpendicular axis and overt he longitudinal axis (roll). The vertical tails give the aircraft the ability to mover over the perpendicular axis (yaw), and the horizontal tails allow the aircraft to pitch (over lateral axis)

2.4 INDUSTRY

In the current market, there are several companies competing and bidding for new defense contractsfor fighter jet. Whether it is within the United States or internationally, the ever-

growing competition has not surrendered its step. Within the United States competition, companies such as Lockheed Martin, Northrop Grumman, General Dynamics, Boeing, and McDonnel Douglas dominate the defense aerospace industry. International companies include, British Aerospace Engineering (BAE Systems), Airbus Group, Sukhoi, Chengdu, Dassault Aviation, and Mikyan to name some of the leading sellers. In study conducted in 2014 by Defense Contractor Marketing, the article revealed that Lockheed Martin had the largest revenue, followed by Boeing, and BAE Systems. Lockheed's success can perhaps be attributed to the JSF (F-35 Lightning II) program [8].

2.5 FUNCTIONAL ORGANIZATION

Functional organizational structure is to be managed in the current organization hierarchical structure, once the project begins operation, the functional units take the various components of the project, and each unit is responsible for its charged component. If the project established, a functional area play a dominant role, functional areas on completion of the project, senior managers will be responsible for project coordination. [9]

Advantages of this structure: First, the use of personnel with greater flexibility, as long as the choice of a suitable functional departments as the project supervisor, the department will be able to provide professional and technical personnel required by the project, and technology experts can also be used by different projects and after completion of the work can go back to his original work [10]. Second, when the project team members leave or leave the company, the functions can be used as the basis for maintaining the continuity of the project; third, functional department can provide a normal career path for professionals [10].

The disadvantage of this structure is: First, projects often lack of focus, each unit has its own core functions of general business, sometimes in order to meet their basic needs,

responsibility for the project will be ignored, especially when the interest taken in the project brought to the unit not the same interest [10]. Second, such organization has certain difficulties in the inter-departmental cooperation and exchanges [10]. Third motivation is not strong enough for project participants, they think the project is an additional burden, and not directly related to their career development and upgrading [10]. Fourth, in such organizational structure, sometimes no one should assume full responsibility for the project, often the project manager is only responsible for part of the project, and others are responsible for the other parts of the project, which leads to difficulties in coordination situation [10].

ADVANTAGES	DISADVANTAGES
Specialization	Double Command
Better Control	Problem of Succession
Reduction of work load	Delay in Decision Making
Higher Efficiency	Complexity
Flexibility	Lack of Coordination
Easier Staffing	Expensive

Figure 5 - Advantages and Disadvantages of a Functional Organization

2.6 MATTRIX ORGANIZATION

Matrix organizational structure is a hybrid form; it loads a level of project management structure on the functional hierarchical structure. According to the relative power of project managers and functional managers, in practice there are different types of matrix systems,

respectively, Functional Matrix: in this matrix, functional managers have greater powers than project managers); Project Matrix: in this matrix, project managers have greater powers than functional managers); Balance Matrix: in this matrix, functional managers and project managers have the equal powers [11].

The advantages of this organizational structure: First, it is the same as functional structure that resources can be shared in multiple projects, which can significantly reducethe problem of redundant staff [11]. Second, project is the focus of work, with a formal designated project manager will make him give more attention to the project, and responsible for the coordination and integration work between different units [11]. Third, when there are multiple projects simultaneously, the company can balance the resources to ensure that all the projects can progress to complete their respective costs and quality requirements [11]. Fourth, the anxiety of project members is reduced greatly after the end of the project, while they are strongly associated with the project; on the other hand, they have a "home" feeling about their functions [11].

The disadvantage is that this organizational structure: First, the matrix structure has exacerbated the tensions between functional manager and project manager [11]. Second, under any circumstances, sharing equipment, resources and personnel among different projects will lead to conflict and competition for scarce resources [11]. Third, in the process of project implementation, the project manager must negotiate and consult with the department managers on various issues, which leadto the delay in decision-making [11]. Fourth, matrix management is not according to the principles of unified management, project members have two bosses, the project manager and functional managers, when their commands are divided, it will make members at a loss [11].

Three different forms of the matrix organizational structure does not necessarily have the

advantages and disadvantages described above: Project Matrix can increase the project's integration, reduce internal power struggle, its weakness is poor control of their functional areas and prone to "project inflammation" [11]. Functional Matrix can provide a better system for managing the conflict between different projects, but maintaining the control of functions is at the cost of inefficient integration of projects; Balanced Matrix can achieve the balance between technology and project requirements better, but its establishment and management is very subtle, is likely to encounter many problems related to matrix organization [11].

ADVANTAGES	DISADVANTAGES
Single Project Focus	Complex relations
Highly Flexible	Project Group not homogenous - Low morale
Effective Command	No Unity of Command
Better Utilization of Services	High concentration on respective functions conflict

Figure 6 - Advantages and Disadvantages of a Matrix Organization

	Functional	Weak Matrix	Balanced Matrix	Strong Matrix	Projectized
Description	Traditional organization with a direct supervisor	The PM and FM share responsibilty, with the FM having more authority	The PM and the FM share respnonsibilty, with each having equal authority	The PM and the FM share responsibilty with the PM having more authority	The PM has all power and authority, but does not mean that he has absolute authority to do everything he
Authority of Project Manager	very low	Low	Low to meduim	Medium to high	high
Resource Availability	very low	Low	low to meduim	Medium to high	high
Who Manages the Project's Budget	Functional Manager	Functional Manager	mixed	Project Manager	project manager
Project Manager Inlvolvement	part tim	Part Time	full time	full time	full time
Project Management Administration Staff	Part Time	Part Time	Full Time	Full time	full time
Advantages	the FM holds accountability for the project	The PM gets some authority to manage the project	The PM and the FM share the responsibily of the project	The PM gets more authority to assign resources and manage the	The PM is adaptive and learn from their own as well as from others experiences
Disadvantages	the PM holds little or no authoruty	The FM can see the PM as a threat and acuase conflict	The PM and the FM can be confused about who manages what	The FM may feel out of the loop	The FM, if there is even one, or he exists, wil have very limited role or authorty

Figure 7 - Advantages and Disadvantages of Functional vs Matrix Organization

`	**Finance**	**Marketing**	**Operations**	**Sales**
	Finance Manger	**Marketing Manager**	**Operstions Manager**	**Sales Manager**
Product A Product manager	Finance Team A	Marketing Team A	Operations Team A	Sales Team A
Product B Product manager	Finance Team B	Marketing Team B	Operations Team B	Sales Team B
Product C Product manager	Finance Team C	Marketing Team C	Operations Team C	Sales Team C
Product D Product manager	Finance Team D	Marketing Team D	Operations Team D	Sales Team D
Product E Product manager	Finance Team E	Marketing Team E	Operations Team E	Sales Team E

Figure 8 - Matrix Organization Example

CHAPTER 3: METHODOLOGY

The methodology for this research consists of two important phases where phase one is the classification of the current methods used by Lockheed Martin for Control Surfaces and Edges structure. Phase two will show an analysis utilizing two DSM examples that render an improved version of the methods used by two different companies. This section will utilize data obtained from a Fortune 500 defense contractor company. The example used is based off the control surfaces and edges group within this company.

3.1 CURRENT ORGANIZATION METHOD

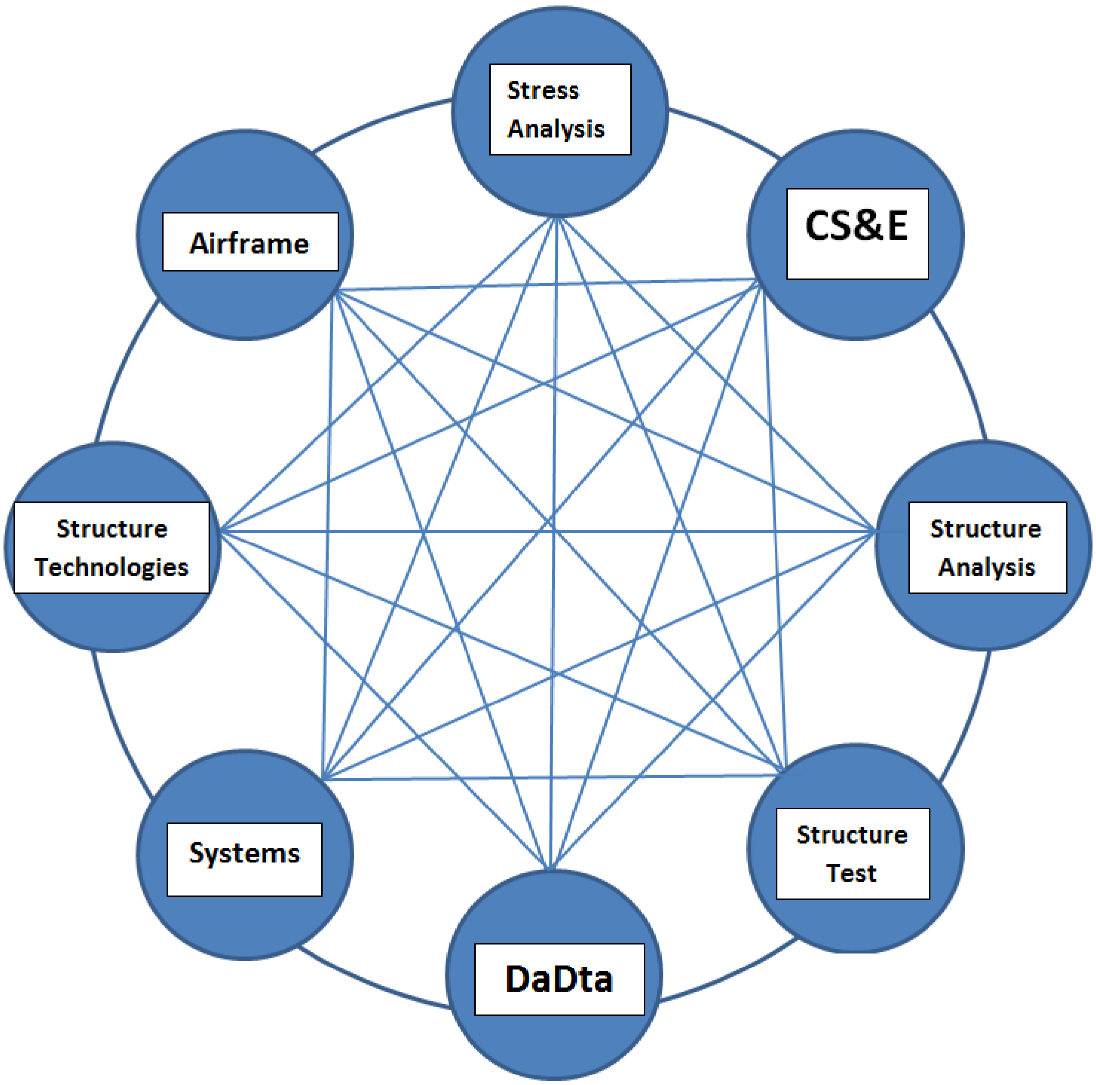


Figure 9 - Current Industry Method within CS&E Team

In a typical organization, many may belive that departmentalized team may work as shown above when is reality it executes most of its actions as the figure shown below.

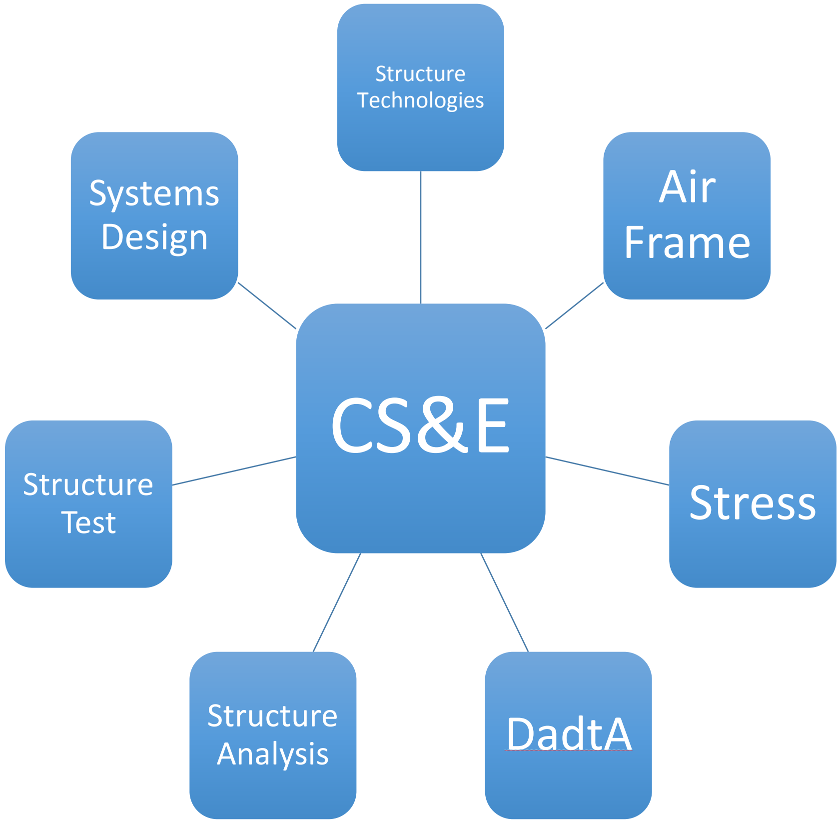


Figure 10 - Current Method using CS&E as an example

As control surfaces dictate and is what stresses the entire airplane. Its communciation and data transfer between other air vehicle systems is crucial. The communication is bi-lateral as other systems must sedn and receive data from whatever control surfaces executes. The same goes for control surfaces and it contains inputs/outputs from the other sytems.

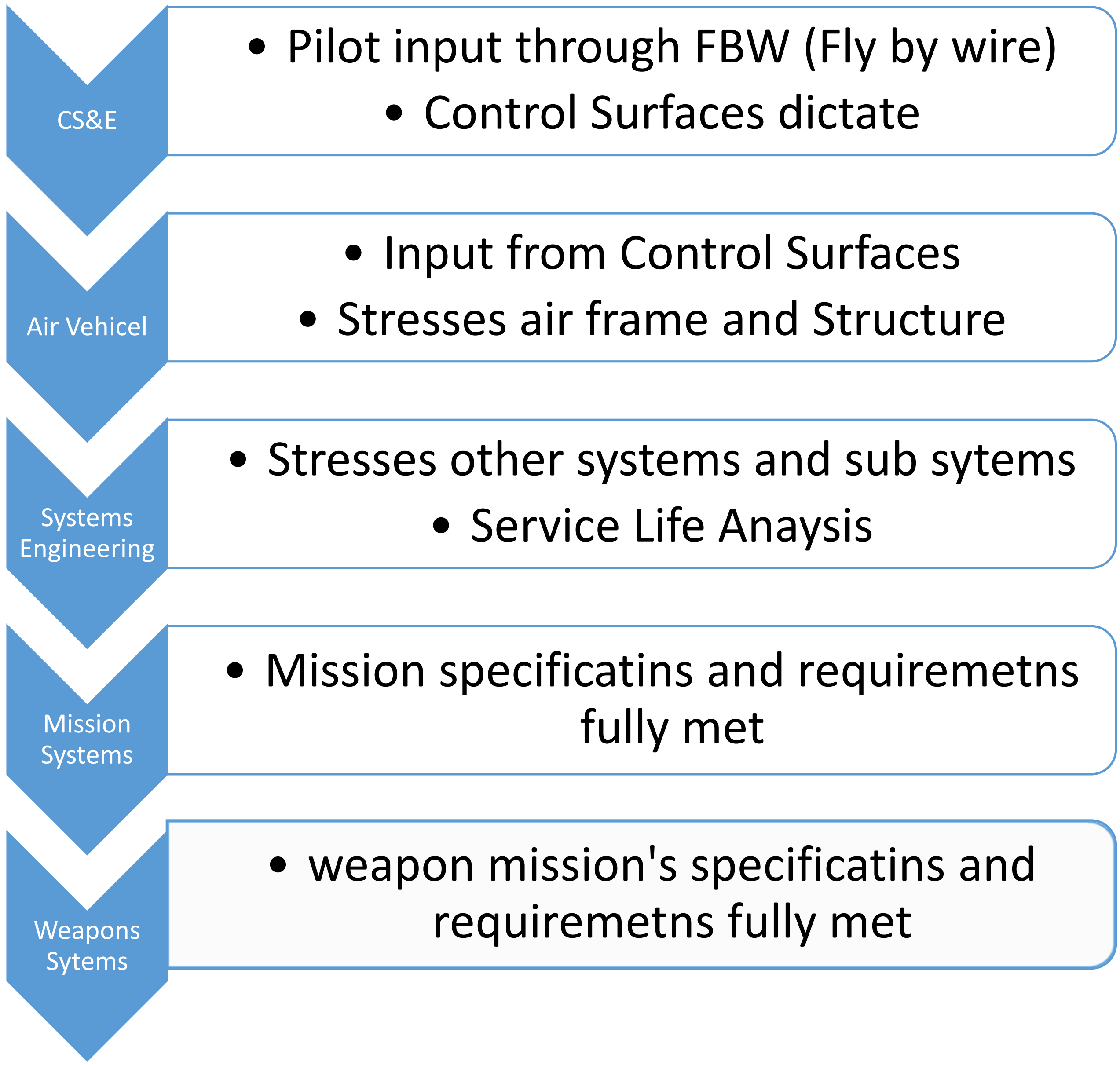


Figure 11 - Sequence of current Method within Air Vehicle Team

Figure 12 - Air Vehicle Team to remaining of Team

IPT = Integrated Performance Team

3.1.1 CURRENT

Lockheed Martin Aeronautics' sector began utilizing the concept of functional and matrix division with the acquisition of the JSF program.

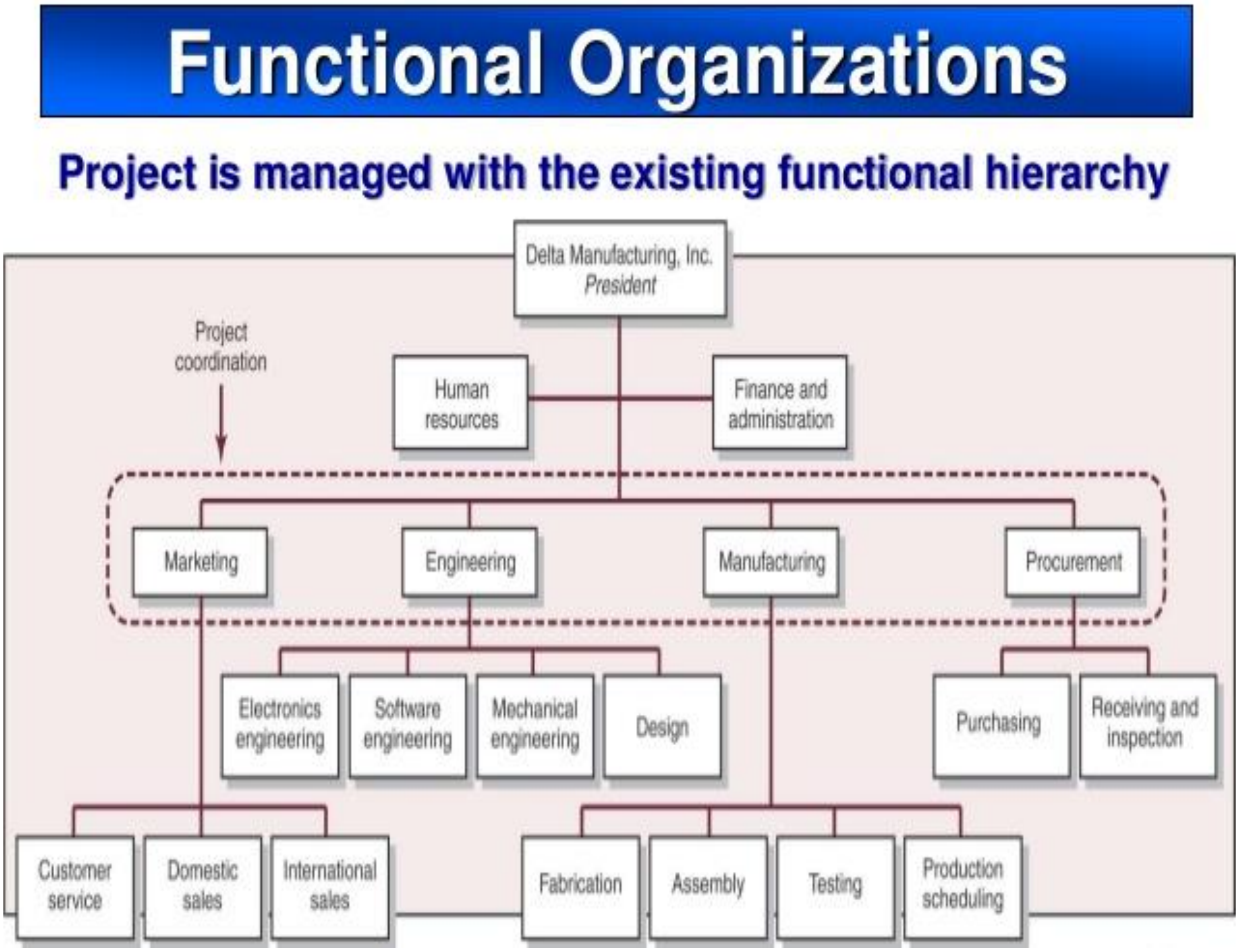


Figure 13 - Departmentalized Functional Organization Example

Delta Manufacturing, Inc. – Michel Baudin

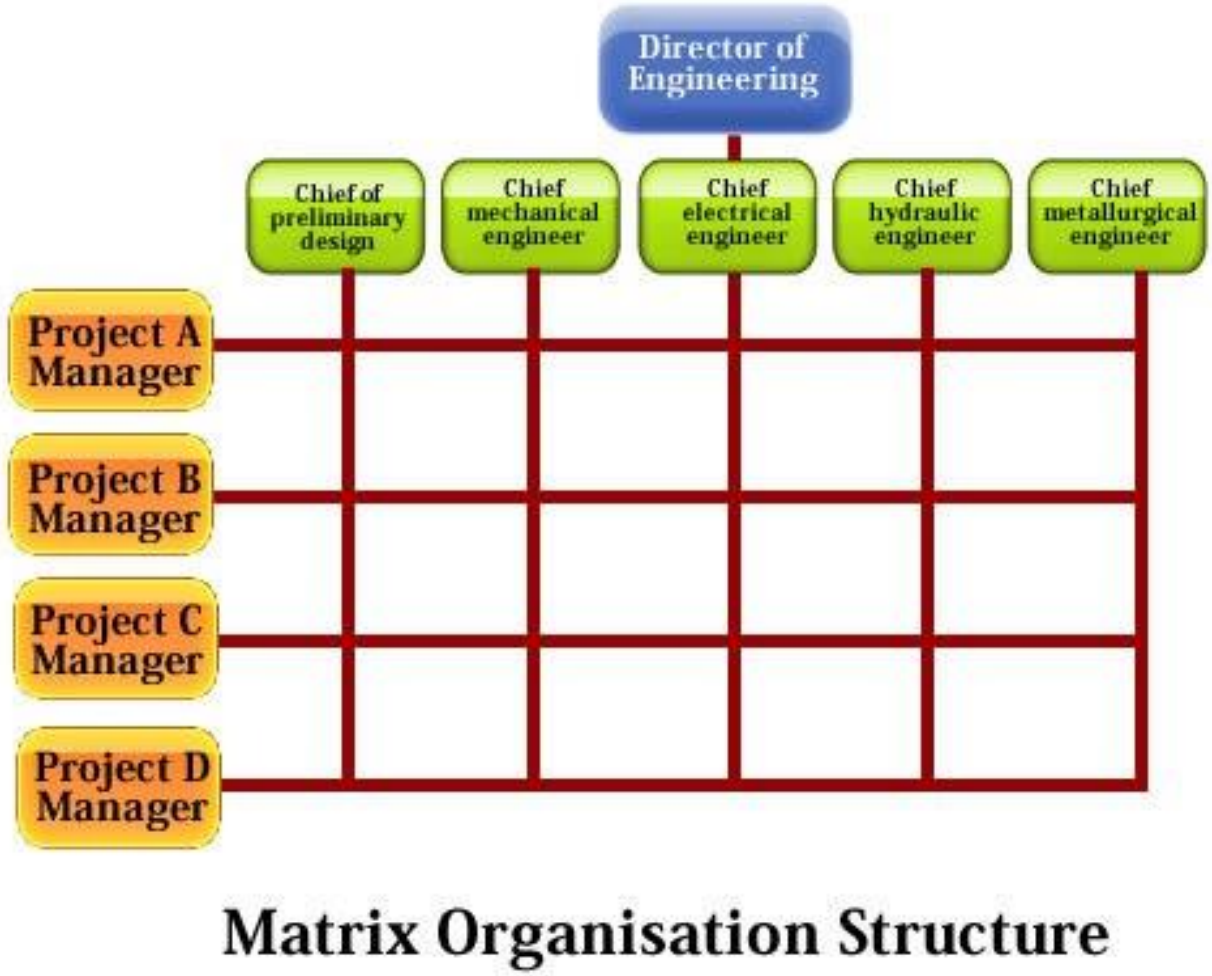
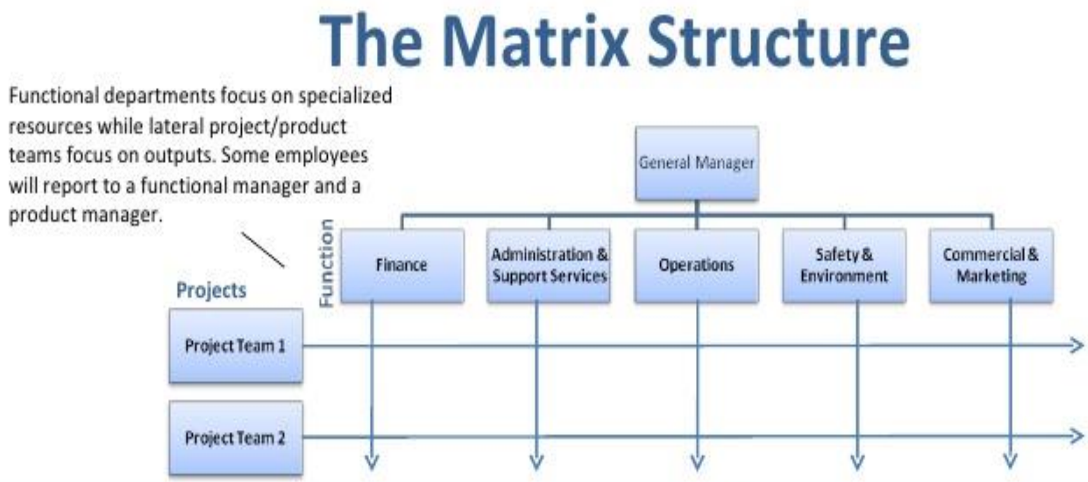


Figure 14 - Departmentalized Matrix Organization Example

Iskander Investments - Houghton Mills Company



Advantages	Disadvantages	Works Best When..
1. Interdependencies between functional departments are managed well 2. Skill diversification and training across functions is easier	1. Difficult to manage and control coordination 2. Employees may face unclear roles and inconsistent job demands	1. The organisation is very large 2. Business environment is uncertain and unpredictable 3. High level of technological interdependency across functions exists 4. The goal is product specialization and innovation

Figure 15 - Matrix Layout and features

Mubeena Group

3.2 EXAMPLE 1

In 1992 McDonnell Douglas set forth to to develop theor F/A-18E/F Super Hornte for the U.S. Navy [1]. The company later realized that it would be a cross functional development team from the previous A-D generation fighter jet. 43 teams were initially assembled for this program, and later diminished. Throughout an eighteen month period, the company assembled teams based on organizational based structure (OBS) and information feedback given from leadership [1]. This process utilized an up and coming tool of its time, DSM. Analyzing the the program with DSM allowed the organizational structure to be assesmbled in 21 teams and work efficacious. The figure below represents the results of the analysis conducted. It can be seen where at first leaders did not know who their team members interacted with and how often. The results would most likely have improved consistency if the team leaders had consulted their entire team before finalizing their repsonses, and follow-up could have addressed any missunderstandings. The frequent interactions among teams in the same part of the organization structure provide some justification for the organizational design [1].

		A	B	C	D	E	F	G	J	K	P	R	T	U	V	W	Y	Z	AA	CC	EE	FF
Inner Wing	A	A	1	1	3	1	1	2	2	2		2		3	2	2			1		1	1
Outer Wing	B	1	B	1	3	1	1	2	2	2		2		3	2	2			1		1	1
LE Flaps	C	1	1	C	1	1	1	2	2	1					2	2			1		3	
Horizontal Tail	D	3	3	1	D	1	1	2	2	1					2	2			1			
TE Flap/Aileron	E	1	1	1	1	E	1	1	2			2	2	2	2	1			3		2	
Manuevering Loads	F	1	1	1	1	1	F	3	1	1	1	1	3	3	2	2	3	3	2	3	1	3
E & B Loads	G	2	2	2	2	1	3	G	1	2				3	2	2	3	3	2	3	1	3
Structural Dev. & Test	J	2	2	2	2	2	1	1	J								3	2	2		2	
Structural Integrity	K	1	1	1	1	1	1	2		K		1					1	1	1		1	
Flt Ctrls Computer Soft.	P						1				P	1	1			3						2
Flying Qual/Control Laws	R	2	2			2	1	3		2	1	R	3	3		2	2		3			
Flt Ctrls Syst Integ Testing	T					2	3				1	2	T						3			2
Weapons Seperation	U	3	3			2	3	3		3		3		U		2	2				1	
Stability & Control	V	2	2	2	2	2	2	2				1		3	V	1					2	
High Speed Drag & Perf.	W	2	2	2	2	1	2	2			3	2		2		W			3	2	2	
Main Landing Gear	Y						3		2	1		2		2			Y	1	1		1	1
NLG/Doors/Hooks	Z						3	3	2	3							1	Z	3	3	2	3
Mechanisms/Flt Controls	AA	1	1	1	1	3	3	3	3			3				3	1		AA		3	2
ECS	CC	3	3	3	3	3	3	3		3						2		2	3	CC		1
Armament	EE	1	1	3		2	1	1	2	2				1	2	2	1	2	3		EE	2
Electrical	FF	1	1				3	3			2		2				1	3	2	1	2	FF

Figure 16 - F/A-18 DSM Example

Frequency of Team Interactions

3 = monthly 2 = weekly 1 = daily

3.3 EXAMPLE 2

General Motors give a secondary example with the design of their Short Block (ST) engine [1]. The initial DSM layout indicated that the original structure enabled only some of dozens of interactions that needed to take place across component teams (CT). In this example, program managers were asked how they addressed the interactions that are not within the STs, and they stated that many of the interactions may not in fact be addressed until a problem arises, potentially much later in the system integration phase of the project [1]. In the reorganizational proposed there were many teams that were disassembled and re-routed to other departments. Some of the CTs (teams and members) were assigned to STs and vice versa [1].

		A	F	G	D	E	I	B	C	J	K	P	H	N	O	Q	L	M	R	S	T	U	V
Engine Block	A	A	1	3	1	3	1	1	1	1	3		1				3	3		1		1	2
Crankshaft	F	1	F	1	1	1	1	2	3	3			2							2	3		2
Flywheel	G	3	1	G			3															2	2
Pistons	D	1	2	3	D	2	2	1	2	2	3	2								3			1
Connecting Rods	E	2	1		1	E	2	3		3													2
Lubrication	I	1	2	3	2	3	I	3	2	3			3				3			3		2	1
Cylinder Heads	B	1	3		2		3	B	1	1	1	2	1		2	3	2	3		2		3	1
Canshaft/Valve Train	C	1	3		3		2	1	C	3												3	2
Water Pump/Cooling	J	1			2		2	1	2	J	2	3	1	3		3		3				3	2
Intake Manifold	K	2					3	1	3	1	K	1	1	2	2	1	1	1	1	2	2		1
Fuel System	P							2		3	1	P	2	3	3	3		3	3			2	1
Accessory Drive	H	1	2				3	1	3	1	1	1	H	2	1	1	2	2	3	3	3	3	1
Air Cleaner	N							3			1	3	1	N	2	1	3						
A.I.R.	O	3						2		3	2		1	2	O	3	1	3			2	3	2
Throttle Body	Q							2		2	1	2	2	1	3	Q		2	1	3	1		2
Exhaust	L	3					3	1		3	2	2	3	3	1		L	1		2	2	3	2
E.G.R.	M	3						2		3	1	3	3		3	3	1	M		3	1	3	2
EVAP	R										3	2				1			R		2	3	
Ignition	S	1	1	1	3		3	1	1	3	2	1	2			1	1	3	3	S	1	1	1
E.C.M.	T	2	2	3			3	3	3	1	2	1	3		2	3	3	2	1	1	T	1	2
Electrical System	U	1	3	2	3		2	3	2	3	3	2	3		3		1	3	3	1	1	U	1
Engine Assembly	V	1	1	2	1	2	1	1	2	2	1	1	2		2	2	2	2	3	1	2	1	V

Figure 17 - GM Short Block DSM Example

Frequency of Team Interactions

3 = monthly   2 = weekly   1 = daily

CHAPTER 4: CASE STUDY

The case study being studied in this research uses data observed and retrieved from a fortune 500 company over the last four years. It begins by showing the current layout of its organization structure and the sectors in which the program is divided into.

4.1 REAL CASE APPLICATION

	Airframe	Systems Design	Stress	DadTa	Structure Technologies	Structure Analysis	Structure Test	CS&E	Requirements	DCMA	Military Specs	Systems Engineering V	Electronic Warfare	Cock Pit	Heads Up Display	Helmet	Block Variants	LLO	Door Test	Pylons	Cargo Bay	A- Variant Cannon	Engine Run	hydromagnetic run	Landing Gear	Electronics	Pressure test	Critical FOD	Fuel Test	Band Test	Flight
Airframe	■	X	X	X	X	X	X	X																							
Systems Design	X	■	X	X	X	X	X	X																							
Stress	X	X	■	X	X	X	X	X																							
DadTa	X	X	X	■	X	X	X	X																							
Structure Technologies	X	X	X	X	■	X	X	X																							
Structure Analysis	X	X	X	X	X	■	X	X																							
Structure Test	X	X	X	X	X	X	■	X																							
CS&E	X	X	X	X	X	X	X	■																							
Requirements									■	X	X	X																			
DCMA									X	■	X	X																			
Military Specs									X	X	■	X																			
Systems Engineering V									X	X	X	■																			
Electronic Warfare													■	X	X	X	X	X													
Cockpit													X	■	X	X	X	X													
heads up display													X	X	■	X	X	X													
helmet													X	X	X	■	X	X													
Block variants													X	X	X	X	■	X													
LLO													X	X	X	X	X	■													
door test																			■	X	X	X									
pylon																			X	■	X	X									
cargo																			X	X	■	X									
A Variant cannon																			X	X	X	■									
engine run																							■	X	X	X	X	X	X	X	X
hydromagnetic run																							X	■	X	X	X	X	X	X	X
landing gear																							X	X	■	X	X	X	X	X	X
electronics																							X	X	X	■	X	X	X	X	X
pressure test																							X	X	X	X	■	X	X	X	X
critical FOD																							X	X	X	X	X	■	X	X	X
fuel test																							X	X	X	X	X	X	■	X	X
band test																							X	X	X	X	X	X	X	■	X
flight																							X	X	X	X	X	X	X	X	■

Figure 18 - Theoretical Functional Organizational Structure

Firgure 4.1 displays how a functional arrangement should be conducted. Each of the individual teams within a program are connected in the form of communication, data and information transfer. There is great communication as this teams work closely with one another and goals are similar. However, this layout puts the program at a deficit, as there is only intra-communication, and not inter-communication from one team to the other. It becomes very difficult to address issues, lead times increase for activities to be done, and in the end can be very costly.

Total number of theoretical connections within a Functional Organization using DSM:

$n^2 - n$, where n = number of activities in each team

$$8^2 - 8 = 56$$

$$4^2 - 4 = 12$$

$$6^2 - 6 = 30$$

$$4^2 - 4 = 12$$

$$9^2 - 9 = 72$$

$$\sum 56 + 12 + 30 + 12 + 72 = 182$$

	Air Vehicle	Airframe	Systems Design	Stress	DadTa	Structure Technologies	Structure Analysis	Structure Test	CS&E	**Systems**	Requirements	DCMA	Military Specs	Systems Engineering V	**Mission Systems**	Electronic Warfare	Cock Pit	Heads Up Display	Helmet	Block Variants	LLO	**Weapon Systems**	Door Test	Pylons	Cargo Bay	A- Variant Cannon	**Flight Test**	Engine Run	hydromagnetic run	Landing Gear	Electronics	Pressure test	Critical FOD	Fuel Test	Band Test	Flight
Air Vehicle	■									X					X							X					X									
Airframe		■	X	X	X	X	X	X	X																											
Systems Design		X	■	X	X	X	X	X	X																											
Stress		X	X	■	X	X	X	X	X																											
DadTa		X	X	X	■	X	X	X	X																											
Structure Technologies		X	X	X	X	■	X	X	X																											
Structure Analysis		X	X	X	X	X	■	X	X																											
Structure Test		X	X	X	X	X	X	■	X																											
CS&E		X	X	X	X	X	X	X	■																											
Systems Engineering	X									■					X							X					X									
Requirements											■	X	X	X																						
DCMA											X	■	X	X																						
Military Specs											X	X	■	X																						
Systems Engineering V											X	X	X	■																						
Mission Systems	X									X					■							X					X									
Electronic Warfare																■	X	X	X	X	X															
Cockpit																X	■	X	X	X	X															
heads up display																X	X	■	X	X	X															
helmet																X	X	X	■	X	X															
Block variants																X	X	X	X	■	X															
LLO																X	X	X	X	X	■															
Weapon Systems	X									X					X							■					X									
door test																							■	X	X	X										
pylon																							X	■	X	X										
cargo																							X	X	■	X										
A Variant cannon																							X	X	X	■										
Flight Test	X									X					X							X					■									
engine run																												■	X	X	X	X	X	X	X	X
hydromagnetic run																												X	■	X	X	X	X	X	X	X
landing gear																												X	X	■	X	X	X	X	X	X
electronics																												X	X	X	■	X	X	X	X	X
pressure test																												X	X	X	X	■	X	X	X	X
critical FOD																												X	X	X	X	X	■	X	X	X
fuel test																												X	X	X	X	X	X	■	X	X
band test																												X	X	X	X	X	X	X	■	X
flight																												X	X	X	X	X	X	X	X	■

Figure 19 - Theoretical Matrix Organizational Structure

Within a matrix layout, all components seem to be similar to that of a functional structure with some exceptions. The advantage matrix has over functional is the transmission of information amongst different teams is more fluid. Due to the hierarchy and "dual boss" configuration, leaders can transfer information to other teams. A pitfall of this is that data may be miss-construed in the process, and a significant lead time is still in play as one must wait on other leaders to obtain the needed information.

Total number of theoretical connections within a Matrix Organization using DSM:

$b^2 - b$, where b = number of teams

$$5^2 - 5 = 20$$

We then utilize the previous information from A functional organization, and sum their respective totals:

20 + 182 = 202

	Airframe	Systems Design	Stress	DadTa	Structure Technologies	Structure Analysis	Structure Test	CS&E	Requirements	DCMA	Military Specs	Systems Engineering V	Electronic Warfare	Cock Pit	Heads Up Display	Helmet	Block Variants	LLO	Door Test	Pylons	Cargo Bay	A- Variant Cannon	Engine Run	hydromagnetic run	Landing Gear	Electronics	Pressure test	Critical FOD	Fuel TesT	Band Test	Flight
Airframe	■	X		X	X	X	X		X	X	X			X			X					X			X						
Systems Design	X	■		X				X	X	X	X		X	X	X		X		X	X	X	X	X	X	X	X	X				X
Stress	X		■	X	X	X	X		X	X	X								X			X			X						X
DadTa	X		X	■					X	X	X											X				X					X
Structure Technologies	X		X	X	■	X	X		X	X	X								X			X			X						X
Structure Analysis	X		X	X	X	■	X		X	X	X								X			X			X						X
Structure Test	X	X	X	X			■		X	X	X								X			X			X						X
CS&E	X	X	X	X	X	X	X	■	X	X	X				X	X		X													X
Requirements	X	X	X	X	X	X	X	X	■	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
DCMA	X	X	X	X	X	X	X	X	X	■	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Military Specs	X	X	X	X	X	X	X	X	X	X	■	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Systems Engineering V									X	X	X	■					X														
Electronic Warfare									X	X	X		■		X	X															X
Cockpit			X	X	X	X	X	X	X	X	X		X	■	X	X	X		X	X	X	X	X	X	X		X		X	X	X
heads up display					X	X	X	X	X	X	X		X		■	X				X	X									X	X
helmet									X	X	X		X		X	■				X										X	X
Block variants	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	■	X	X	X	X	X	X	X	X	X	X	X	X	X	X
LLO								X	X	X	X		X				X	■	X		X										X
Hatch test	X		X	X	X	X	X		X	X	X				X			X	■		X	X		X				X			
pylon	X		X	X					X	X	X				X	X				■											
Cargo Bay	X		X	X	X	X	X		X	X	X				X	X		X	X	X	■		X		X			X	X		X
A Variant cannon	X			X					X	X	X				X							■									
engine run		X	X		X	X	X		X	X	X				X								■	X				X	X		X
hydromagnetic run		X			X	X	X	X	X	X	X				X		X		X	X	X	X	X	■	X		X	X	X		X
landing gear	X	X		X	X	X	X		X	X	X				X			X	X						■						
electronics		X			X	X	X	X	X	X	X		X		X	X			X	X	X	X	X	X	X	■				X	X
pressure test	X	X			X	X	X		X	X	X												X				■	X	X		X
critical FOD									X	X	X																X	■	X		
fuel test	X	X							X	X	X				X								X				X	X	■		X
band test		X							X	X	X				X					X										■	
flight	X	X	X	X	X	X	X		X	X	X		X		X	X															■

Figure 19 - Actual Data Observed of Organizational Structure

Figure 4.3 exposes the actual structure where a hyper-connected layout is being used. It is quite difficult to follow the direction of inputs and outputs, hence making it difficult to keep proper and organized information transfer. In some teams, there is redundancy, and at times, absolutely no communication. It is a “first come, first served basis” when it come to realizing actions. When “hot” (high priority, high importance) actions must be accomplished there is no room as some team members may be overwhelmed and over loaded with other work that they receive without them being the correct channel of communication. It is a fact that this issue must be resolved, rendering an improved version of matrix, functional, and actual structures

Total number of actual connections from the observed data over four years:

$$\sum of\ all\ connection\ in\ every\ row$$

$$\sum 12 + 20 + 12 + 8 + 12 + 12 + 11 + 14 + 30 + 30 + 30 + 4 + 6 + 24 + 13 + 8 + 30 + 9 + 15 + 8 + 19 + 6 + 13 + 20 + 12 + 20 + 12 + 5 + 10 + 6 + 13 = 444$$

	Airframe	Systems Design	Stress	DadTa	Structure Technologies	Structure Analysis	Structure Test	CS&E	Requirements	DCMA	Military Specs	Systems Engineering V	Electronic Warfare	Cock Pit	Heads Up Display	Helmet	Block Variants	LLO	Door Test	Pylons	Cargo Bay	A- Variant Cannon	Engine Run	hydromagnetic run	Landing Gear	Electronics	Pressure test	Critical FOD	Fuel TesT	Band Test	Flight
Airframe	■	X		X	X	X	X		X	X	X			X			X					X			X						
Systems Design	X	■		X				X	X	X	X		X	X	X		X		X	X	X	X	X	X	X	X	X				X
Stress	X		■	X	X	X	X		X	X	X								X			X			X						X
DadTa	X		X	■					X	X	X											X				X					X
Structure Technologies	X		X	X	■	X	X		X	X	X								X			X			X						X
Structure Analysis	X		X	X	X	■	X		X	X	X								X			X			X						X
Structure Test	X	X	X	X			■		X	X	X								X			X			X						X
CS&E	X	X	X	X	X	X	X	■	X	X	X				X	X		X													X
Requirements	X	X	X	X	X	X	X	X	■	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
DCMA	X	X	X	X	X	X	X	X	X	■	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Military Specs	X	X	X	X	X	X	X	X	X	X	■	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Systems Engineering V									X	X	X	■					X														
Electronic Warfare									X	X	X		■		X	X															X
Cockpit			X	X	X	X	X	X	X	X	X		X	■	X	X	X		X	X	X	X	X	X	X		X		X	X	X
heads up display					X	X	X	X	X	X	X		X		■	X				X	X									X	X
helmet									X	X	X		X		X	■				X										X	X
Block variants	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	■	X	X	X	X	X	X	X	X	X	X	X	X	X	X
LLO								X	X	X	X		X				X	■	X		X										X
Hatch test	X		X	X	X	X	X		X	X	X				X			X	■		X	X		X				X			
pylon	X		X	X					X	X	X				X	X				■											
Cargo Bay	X		X	X	X	X	X		X	X	X				X	X		X	X	X	■		X		X			X	X		X
A Variant cannon	X			X					X	X	X				X							■									
engine run		X	X		X	X	X		X	X	X				X								■	X				X	X		X
hydromagnetic run		X			X	X	X	X	X	X	X				X		X		X	X	X	X	X	■	X		X	X	X		X
landing gear	X	X		X	X	X	X		X	X	X				X			X	X						■						
electronics		X			X	X	X	X	X	X	X		X		X	X			X	X	X	X	X	X	X	■				X	X
pressure test	X	X			X	X	X		X	X	X												X				■	X	X		X
critical FOD									X	X	X																X	■	X		
fuel test	X	X							X	X	X				X								X				X	X	■		X
band test		X							X	X	X				X					X										■	
flight	X	X	X	X	X	X	X		X	X	X		X		X	X															■

Figure 20 - Actual Data Observed of Organizational Structure

[red box] = some outliers within organizational structure that must be addressed.

4.2 RESULTS

	Air Vehicle	Airframe	Systems Design	Stress	DadTa	Structure Technologies	Structure Analysis	Structure Test	CS&E	**Systems**	Requirements	DCMA	Military Specs	Systems Engineering V	**Mission Systems**	Electronic Warfare	Cock Pit	Heads Up Display	Helmet	Block Variants	LLO	**Weapon Systems**	Door Test	Pylons	Cargo Bay	A- Variant Cannon	**Flight Test**	Engine Run	hydromagnetic run	Landing Gear	Electronics	Pressure test	Critical FOD	Fuel Test	Band Test	Flight
Air Vehicle		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Airframe	X		X	X	X	X	X	X	X	X	X	X	X		X							X					X									
Systems Design	X	X		X	X	X	X	X	X	X	X	X	X		X							X					X									
Stress	X	X	X		X	X	X	X	X	X	X	X	X		X							X					X									
DadTa	X	X	X	X		X	X	X	X	X	X	X	X		X							X					X									
Structure Technologies	X	X	X	X	X		X	X	X	X	X	X	X		X							X					X									
Structure Analysis	X	X	X	X	X	X		X	X	X	X	X	X		X							X					X									
Structure Test	X	X	X	X	X	X	X			X	X	X	X		X							X					X									
CS&E	X	X	X	X	X	X	X	X		X	X	X	X		X							X					X									
Systems Engineering	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Requirements	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
DCMA	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Military Specs	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Systems Engineering V	X									X	X	X	X		X							X					X									
Mission Systems	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Electronic Warfare	X									X	X	X	X		X		X	X	X	X	X	X					X									
Cockpit	X									X	X	X	X		X	X		X	X	X	X	X					X									
heads up display	X									X	X	X	X		X	X	X		X	X	X	X					X									
helmet	X									X	X	X	X		X	X	X	X		X	X	X					X									
Block variants	X									X	X	X	X		X	X	X	X	X		X	X					X									
LLO	X									X	X	X	X		X	X	X	X	X	X		X					X									
Weapon Systems	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
door test	X									X	X	X	X		X							X		X	X	X	X									
pylon	X									X	X	X	X		X							X	X		X	X	X									
cargo	X									X	X	X	X		X							X	X	X		X	X									
A Variant cannon	X									X	X	X	X		X							X	X	X	X		X									
Flight Test	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X
engine run	X									X	X	X	X		X							X					X		X	X	X	X	X	X	X	X
hydromagnetic run	X									X	X	X	X		X							X					X	X		X	X	X	X	X	X	X
landing gear	X									X	X	X	X		X							X					X	X	X		X	X	X	X	X	X
electronics	X									X	X	X	X		X							X					X	X	X	X		X	X	X	X	X
pressure test	X									X	X	X	X		X							X					X	X	X	X	X		X	X	X	X
critical FOD	X									X	X	X	X		X							X					X	X	X	X	X	X		X	X	X
fuel test	X									X	X	X	X		X							X					X	X	X	X	X	X	X		X	X
band test	X									X	X	X	X		X							X					X	X	X	X	X	X	X	X		X
flight	X									X	X	X	X		X							X					X	X	X	X	X	X	X	X	X	

Figure 21 - Results of Organizational Structure desired utilizing DSM

	Air Vehicle	Airframe	Systems Design	Stress	DadTa	Structure Technologies	Structure Analysis	Structure Test	CS&E	Systems	Requirements	DCMA	Military Specs	Systems Engineering V	Mission Systems	Electronic Warfare	Cock Pit	Heads Up Display	Helmet	Block Variants	LLO	Weapon Systems	Door Test	Pylons	Cargo Bay	A- Variant Cannon	Flight Test	Engine Run	hydromagnetic run	Landing Gear	Electronics	Pressure test	Critical FOD	Fuel Test	Band Test	Flight
Air Vehicle	■	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Airframe	X	■	X	X	X	X	X	X	X	X	X	X	X		X							X					X									
Systems Design	X	X	■	X	X	X	X	X	X	X	X	X	X		X							X					X									
Stress	X	X	X	■	X	X	X	X	X	X	X	X	X		X							X					X									
DadTa	X	X	X	X	■	X	X	X	X	X	X	X	X		X							X					X									
Structure Technologies	X	X	X	X	X	■	X	X	X	X	X	X	X		X							X					X									
Structure Analysis	X	X	X	X	X	X	■	X	X	X	X	X	X		X							X					X									
Structure Test	X	X	X	X	X	X	X	■		X	X	X	X		X							X					X									
CS&E	X	X	X	X	X	X	X	X	■	X	X	X	X		X							X					X									
Systems Engineering	X	X	X	X	X	X	X	X	X	■	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Requirements	X	X	X	X	X	X	X	X	X	X	■	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
DCMA	X	X	X	X	X	X	X	X	X	X	X	■	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Military Specs	X	X	X	X	X	X	X	X	X	X	X	X	■	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Systems Engineering V	X									X	X	X	X	■	X							X					X									
Mission Systems	X	X	X	X	X	X	X	X	X	X	X	X	X	X	■	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Electronic Warfare	X									X	X	X	X		X	■	X	X	X	X	X	X					X									
Cockpit	X									X	X	X	X		X	X	■	X	X	X	X	X					X									
heads up display	X									X	X	X	X		X	X	X	■	X	X	X	X					X									
helmet	X									X	X	X	X		X	X	X	X	■	X	X	X					X									
Block variants	X									X	X	X	X		X	X	X	X	X	■	X	X					X									
LLO	X									X	X	X	X		X	X	X	X	X	X	■	X					X									
Weapon Systems	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	■	X	X	X	X	X	X	X	X	X	X	X	X	X	X
door test	X									X	X	X	X		X							X	■	X	X	X	X									
pylon	X									X	X	X	X		X							X	X	■	X	X	X									
cargo	X									X	X	X	X		X							X	X	X	■	X	X									
A Variant cannon	X									X	X	X	X		X							X	X	X	X	■	X									
Flight Test	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	■	X	X	X	X	X	X	X	X	X
engine run	X									X	X	X	X		X							X					X	■	X	X	X	X	X	X	X	X
hydromagnetic run	X									X	X	X	X		X							X					X	X	■	X	X	X	X	X	X	X
landing gear	X									X	X	X	X		X							X					X	X	X	■	X	X	X	X	X	X
electronics	X									X	X	X	X		X							X					X	X	X	X	■	X	X	X	X	X
pressure test	X									X	X	X	X		X							X					X	X	X	X	X	■	X	X	X	X
critical FOD	X									X	X	X	X		X							X					X	X	X	X	X	X	■	X	X	X
fuel test	X									X	X	X	X		X							X					X	X	X	X	X	X	X	■	X	X
band test	X									X	X	X	X		X							X					X	X	X	X	X	X	X	X	■	X
flight	X									X	X	X	X		X							X					X	X	X	X	X	X	X	X	X	■

Figure 22 - Results of Organizational Structure desired utilizing DSM (detailed)

The above figure depicts the final verdict that was reached after the analysis. The reulsts were gathered from comparing previously used examples in industry to those used currently used in bulidng a fifth generation fighter jet, parallel to using an excell added program from Soo-Haeng Cho and Steven D. Eppinger from Massachusetts Institute of Technology. Throughout this paper, the control surfaces team was used as an example to better encompass the main idea. It can be shown that originally the control surface team was muc integrated with the remaining of the aor vehicel team. The goal was to

cluster identify those similarioties onto the overall organiational strucutre of the program. The current actual method used ois hyper connnected and results in many redundancies. The program and analyis was able to identify clusters and the examples lead to one to identify other interactions that are a must. Under the Systems team – requiremtns, DCMA, and military specs – had to interact with the entire program. This is due to the fact that at every single step of the process, there must be some type of verification and validation executed by the customer , third party, or internal audits.

The red blocks are the clutsers that were formed within the teams. The sepration of teams leads to dynamic intra communication, as the work achieved by that team is similar in nature. The overabundance of information, data, and communication from team members to other team's members is terminated in most cases by using the leader as the source of communication. This method also creastes a validation step where leadership will determine whether the inputs given are proper for their team members or sent to another department/team. This criteria is represented by the green highlighted part.

Total number of actual connections from the observed data over four years:

$$\sum of\ all\ connection\ in\ every\ row = 639$$

CHAPTER 5: CONCLUSION

5.1 SUMMARY

Engineering companies from electronic circuits to defense contractors, rely on the composition of teams, departments, and how worker's talents are allocated. It is important to identify efficient methods to organize such aspects, and allow information, data, and communication flow to obtain the maximum benefits of it. It has been proven that the high complexity of a programs triggers different problems, especially in the organizational structure planning. It becomes difficult to achieve a lean environment without a classification of tasks, member reporting, leaders, and teams into groups. With a great number of resources to organize, it is urgent to generate not only an efficient but coincidentally and effective arrangement. However, none of the existing organizational structure attempts have effectively resolve this issue. For this reason, a unique clustering method is proposed to comply with the requirements of this area. Its results exhibit a new, more practical and efficient way to classify necessary interaction.From the results in this study it can be determined that one of the most vital features to design before the production of a program is the organizational layout of the program.

	Number of Connections
Theoretical Functional Organization	182
Theoretical Matrix Organization	202
Data Observed	444
Theoretical Results	639

Figure 23 - Summary of number of connections

5.2 RECOMMENDATIONS AND FUTURE WORK

There is a fact that the model and analysis in this work can be improved upon. If more accurate and detailed information can be gathered from the source, the analysis can produce a better outcome. The analysis conducted was based on observations over a four-year course, however, with such projects and programs four years are just a mere representation of the surface. There are many softwares and/or add-ons to existing programs to analyze structural organization. Some projects even hire teams that dedicate their skills to deliver a better outcome throughout the life cycle of the project. Hence, there is actually one suggestion that can be made towards the way organizational structures come to a verdict. This work utilized matrices, as a tool for analysis, a computerized tool based on a DSM algorithm would significantly improve results. This tool must have a series of inputs that analyzes program complexity, talent acquisition, talent required, number of specific workers needed in each field, program length, budget, and number of more criteria that are sometimes overlooked.

REFERENCES

[1] Eppinger, S., & Browning, T. (2012). *Design structure matrix methods and applications*. Cambridge, Mass.: MIT Press.

[2] Sharman, D.M. and Yassine, A.A. 2004. Characterizing complex product architectures. Systems Engineering, 7 (1), 35-60.

[3] Yu, T.L., Goldberg, D.E., Sastry, K., Lima, C.F. and Pelikan, M. 2009. Dependency structure matrix, genetic algorithms, and effective recombination. Evolutionary Computation, 17 (4). 595-626.

[4] Yassine, Ali A..*An Introduction to Modeling and Analyzing Complex Product Development Processes Using the Design Structure Matrix (DSM) Method.* Urbana, IL.: University of Illinios

[5] Matthew Bell, Mark Bobbi and Keri Wagstaff-Smith, "JSF : Weighing up the partner nation benefits," in *Jane's Defence Weekly*, 3 February 2010, p. 23.

[6] Pierre Tran, "Mideast Setback for Rafale, Dassault," in *Defense News*, 20 November 2011

[7] Kate Brannen, "Senators Question Move to Shift Funds to JSF ," in *Defense News*, 14 July 2011; Gopal Ratnam and Tony Capaccio, "Panetta says Budget Cuts may Kill Lockheed's F-35 Jet," in *Bloomberg*, 15 November 2011.]

[8] Lieutenant-General André Deschamps, "Meet the F-35 *Lightning II* – Canada's Next Fighter," in *Canadian Military Journal*, Vol. 11, No.1 (2010), p. 50.

[9] Cross-Functional Teams in New Product Development. (n.d.). *Organizing Cross-Functional New Product Development Projects*, 7-48.

[10] Agnihotri, A. (2014). Impact of Strategy-Capital Structure on Firms' Overall Financial Performance. *Strat. Change Strategic Change*,*23*(1-2), 15-20.

[11] Kuprenas, J. A. (2003). Implementation and performance of a matrix organization structure. *International Journal of Project Management*,*21*(1), 51-62.

[12] Browning, T. (2000). Using the Design Structure Matrix (DSM) for Process Integration. Lockheed Martin Aeronautics Company.

[13] Browning, T. R. Applying the Design Structure Matrix to System Decomposition and Integration Problems: A Review and New Directions.

[14] Browning, T. (n.d.). Applying the design structure matrix to system decomposition and integration problems: A review and new directions. *IEEE Transactions on Engineering Management IEEE Trans. Eng. Manage.,* 292-306.

[15] Wang, H., Chignell, M., & Ishizuka, M. (n.d.). Are two talking heads better than one? *Proceedings of the 11th International Conference on Intelligent User Interfaces - IUI '06*.

[16] Rogers, J. (1996). DeMAID/GA - An enhanced design manager's aid for intelligent decomposition. *6th Symposium on Multidisciplinary Analysis and Optimization*.

[17] Zhang, H. (n.d.). Product Development Processes Management Based on Design Structure Matrix (DSM) Method. *2008 4th International Conference on Wireless Communications, Networking and Mobile Computing*.

[18] Park, M., Ham, Y., Lee, H., & Kim, W. (2010). Development of Design Process Management Model using Dependency Structure Matrix for Constructability. *Korean Journal of Construction Engineering and Management,* 65-74.

[19] Nikanjam, A., Sharifi, H., Helmi, B., &Rahmani, A. (n.d.). A new DSM clustering algorithm for linkage groups identification. *Proceedings of the 12th Annual Conference on Genetic and Evolutionary Computation - GECCO '10*.

[20] Schmidt, III Robert, Deamer, Jason, Austin, Simon (2011) Understanding adaptability through layer dependencies. *International Conference on Engineering Desing – ICED1.*

APPENDIX I – USER GUIDE for DSM@MIT ver 1.9

	Inputs	Outputs
Structuring	• A list of tasks • Information flows among tasks • Information flow patterns	• Design Structure Matrix (Identification of loops and process hierarchies among tasks) • Differentiation of planned & unplanned iterations • Identification of non-binding dependencies • A critical dependency sequence and level slack of tasks

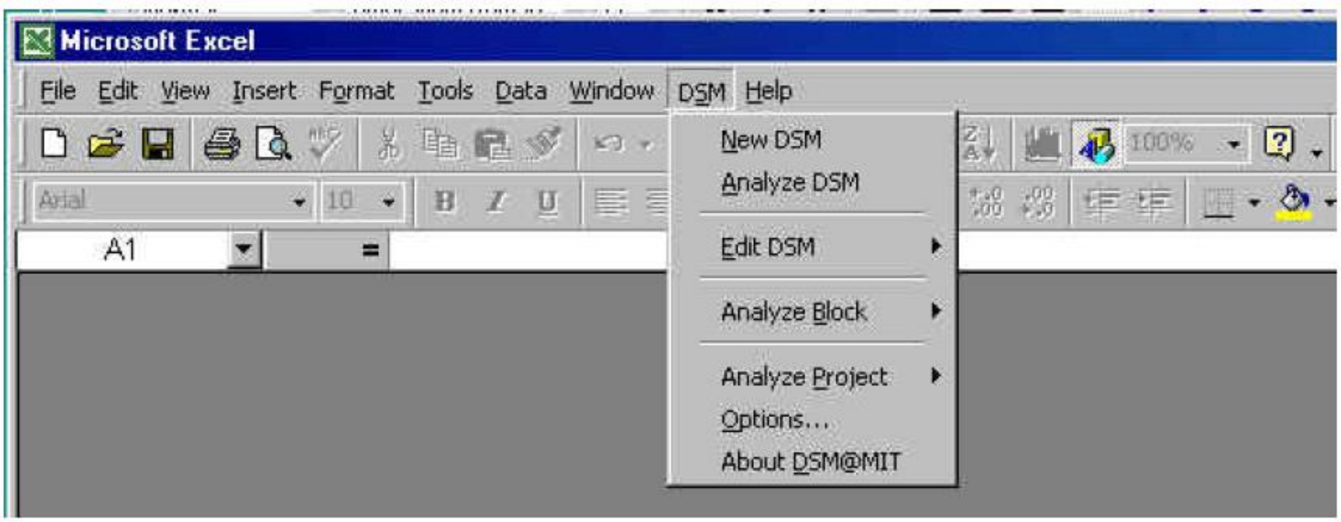


FIGURE 2. ADD-IN MENU IN EXCEL

Project Name		<NOTE>			1. Enter Project Name at (2,A)											
Sample					2. Enter all task names for entries in DSM											
Task Name		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
a	1															
b	2	1														
c	3	2										1				
d	4			2								1				
e	5		1													
	6															
f	7		1			2										
g	8	1		1												
h	9		2			1								1		
i	10					2		1								
j	11				1				1							
k	12									2				2		
l	13												1			
m	14								1			1				
n	15										1			1	1	

A1. Rank Positional Weight (RPW)

A rework-adjusted rank positional weight of task *i* is defined as follows:

$$rpw_i = d_i + \sum_j d_j$$

where, d_i: rework-adjusted duration of task *i* which is defined as the expected value of the sum of the duration of its first execution and the total amount of successive rework it creates for its predecessors, assuming no resource constraints in the project network.

$\sum_j d_j$: sum of all rework-adjusted durations over all successors of task *i*

(Note: a set of successors includes all downstream tasks that receive outputs from the task.)

By adding the summation part of the rank positional weight, it measures global importance of a task while it measures only local importance among neighbor tasks without it.

A2. Cumulative Resource Equivalent Duration (CUMRED)

Cooper[4] defined a cumulative resource equivalent duration of task i of each resource as follows:

$$RUD_k = L_k + E_k / R_k$$

where, RUD_k : resource usage duration of resource k

L_k : last time period of requirement for resource k

E_k : total excess requirement for resource k

R_k : total available amount of resource k

$RUDMAX = Maximum\ \{RUD_k\}$ where $k = 1, 2, \ldots, K$ (number of resources)

$$RED_i = \sum_{k=1}^{K} (r_{ik} \ / \ R_k) \cdot (RUD_k \ / \ RUDMAX) \cdot d_i$$

where, RED_i : resource equivalent duration of task i

r_{ik} : amount of resource k required by task i

$$CUMRED_i = RED_i + \sum_j RED_j$$

where, $CUMRED_i$: cumulative resource equivalent duration of task i

$\sum_j RED_j$: sum of *RED* over all successors of task i

VITA

Israel Michel was born in El Paso, Texas; he is the second born of a family of three. He completed all his academic education in El Paso before attending college in College Station, Texas; Texas A&M University. He acquired his Bachelor of Science degree with a minor in business in the spring of 2014 in Mechanical Engineering. In the fall of 2014, he enrolled in the masters of Science program in systems engineering at the University of Texas at El Paso.

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