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Research Article

The Development of the Carrier Aviation Support System Architecture Using DoDAF

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Abstract: This study describes a development of aircraft carrier aviation support system architecture using DoDAF. The aircraft carrier, warship doing role of mobile sea airbase in offensive and defensive mission, is super system that is comprised of carrier itself and carrier-based air wing. Performing critical role in step with aviation operations in carrier-air wing interactions, the aviation support system of aircraft carrier is also system of systems. It is required to complex and integrated approach based on systems engineering in establishing concept of this complex systems. In this view, this study established an operational scenario and derived operational requirements by identifying aviation operations environment on deck of aircraft carrier. It is presented the operational architecture of the carrier aviation support system by using DoDAF and CASE tool CORE.

Keywords: Aircraft carrier (system), aviation support system, carrier air wing, DoDAF (Department of Defense Architecture Framework), super system, system of systems

INTRODUCTION

In modern warfare, the aircraft is the essential power and using this proper time, proper place is that is, the way of winning the war. In future warfare, the aircraft is also will be able to mobile farther and faster and use larger range, hence it will be continue to keep the key position of military power in whether manned or unmanned systems.

The aircraft carrier is the warship doing the role of sea airbase for offensive and defensive mission using this aircraft and the super system comprised of carrier itself and embarked air wing (Hermann *et al*., 1991; Defense Science Board Task Force, 2002). And the carrier aviation support system, performing the key role in carrier-air wing interactions in step aviation operations from launch to recovery, is also the system of systems. The carrier aviation support system is essential to integrate effectively the distinctive systems of warship and aircraft and operate the aircraft safely on limited deck and therefore it is very important establishing the operational concept of this system. Establishing the operational concept of this complex system requires complex and integrated approach based on systems engineering. Recently in the U.S. Navy and several University, a number of study about modeling aircraft carrier air operations was performing (Angelyn, 1998, 1999; Erdem, 2003; Jason, 2003).

In this viewpoint, this study describes the develop process carrier aviation support system operational architecture by systems engineering approach. This study draws the operational scenario and operational requirements by identifying the carrier's mission and aviation operations' environment on deck in stage air operations and presents the carrier aviation support system operational architecture using CASE (Computer Aided Systems Engineering) tool CORE (David, 2011).

Problem statement: The ROK Navy is operating the ROKS Dokdo the largest warship in Asia from 2007. The ROKS Dokdo has a platform type large flight deck and hangar deck for operating aircraft effectively, but air operations is somewhat limited due to small displacement and simultaneously carrying amphibious force. In 2013, at the Confirmation Hearing, the new Joint Chiefs of Staff mentioned the need of acquiring carrier and at the Inspect of the Government Offices, there was a report that the ROK Navy is studying a plan ROKS Dokdo rebuild to light carrier capable of operating STOVL and acquire two 30,000 ton class carriers until 2032. This plan would be an intention developing the concept of carriers as a main role operating aircraft based on ROKS Dokdo. Meanwhile, the ROK Navy have accumulated sufficient infrastructure and knowhow required to build ship itself by ship acquisition program, but building and employing the system operating a number of aircraft on board is another issue. In this view, it is essential to understand about carrier aviation support system and it needs to advanced research.

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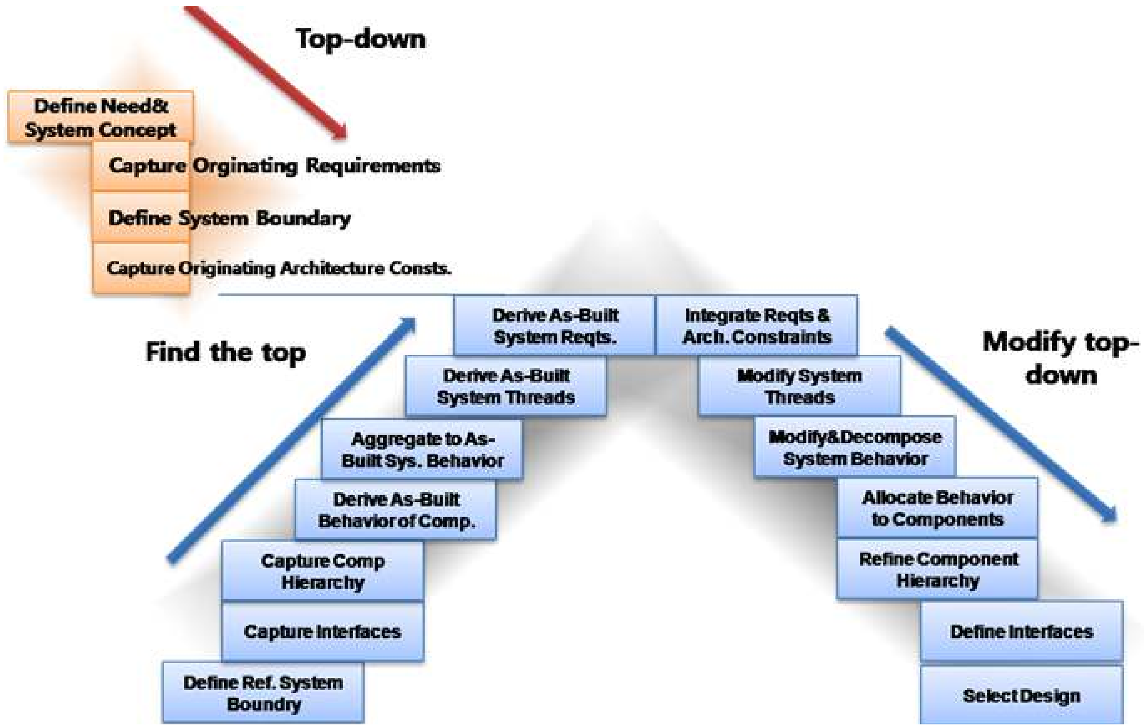

Fig. 1: System re-engineering process

METHODOLOGY

System engineering process: In general, the development precedents can be found for commercial system development projects. The risk and operational burden can be mitigated significantly if the legacy architecture is reused.

Sage defined the product re-engineering as reconfiguration of conventional products' internal mechanism or functions into functional and non-functional form through the inspection, research, identification and modification of such internal mechanism or functions in order to apply new technology while achieving essential objectives of conventional products (Sage and Lynch, 1998; Sage and Rouse, 2009). According to the definition drawn by Sage, re-engineering means the product process that involves the sequence of forward-engineering, reverse-engineering and re-engineering. Figure 1 presents a diagram of the re-engineering process. The re-engineering process implements the net-engineering process that carries out the requirement definition process by identifying the needs and system concepts of initial stakeholders. In addition, the re-engineering process carries out reverse-engineering process that derives system requirements by analyzing the reference system. Finally, along with the requirements that have been derived in that way, the re-engineering process is implemented to carry out the solution definition process again by integrating the requirements that have been generated earlier.

While performing the re-engineering process, the interface obtains interface relationship between the system of reference system or sub-components in the process of reverse-engineering and is identified through the solutions definition process for the target system in the re-engineering process. The interface, which has been identified by implementing the re-engineering process in the aforesaid way, is managed through CASE Tool.

CASE tool: Currently, many system engineers are using the 'Computer Added System Engineering Tool' to perform the Model-Based System Engineering design and many related cases can be found (Do and Cook, 2012; Bonanne, 2014; Matar *et al*., 2014; Scheeren and Pereira, 2014; Góngora *et al*., 2015). MBSE presents reasonable alternative systems through the modeling and simulation from various viewpoints at system level and the response to the vast amount of information by using the computational support tool, thereby reducing the number of prototypes that are created. Moreover, MBSE can ensure trace ability for various requirements ranging from stakeholders' requirements to system validation requirements and increase productivity of works. The system design data, built into database, can facilitate the use and reuse of information related to the existing system in the development of similar systems.

In this regard, the use of System Engineering Computational support tool (CASE Tool) will facilitate system engineering process implementation ranging from the analysis of requirements to the realization of system architecture. Using this tool, the carrier aviation support system project provided simultaneous

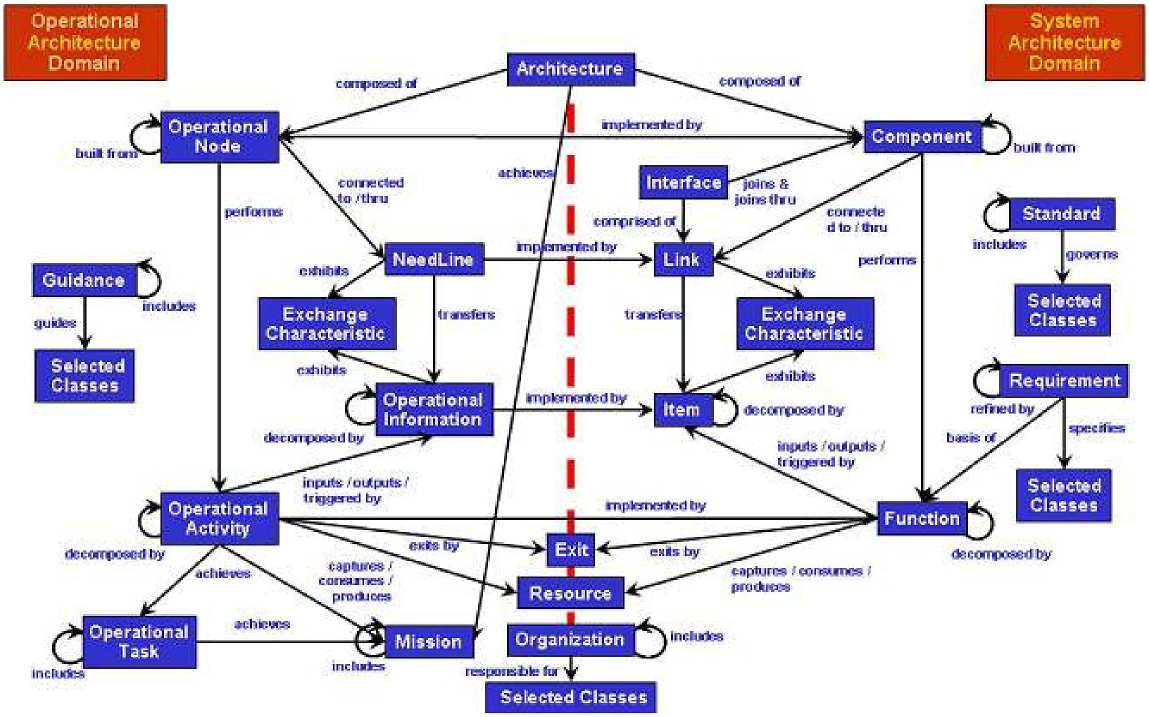

Fig. 2: The schema for system architecting and modeling using DoDAF (Joseph and James, 2002)

development environment of many developers and particularly, system design environment. In this study, the Vitech CORE was used as the tool.

Then, to build the integrated systems model environment that uses the computational support tool, the definition of schema is required which defines the data elements, relationship among such data elements and attributes of the elements.

Figure 2 presents the schema built for the system design and architecture using DoDAF in this study (Joseph and James, 2002). The following Chapter describes the re-engineering process for making up systems architecting that has been explained above and the system design activities using the computational support tool that supports the system model environment within the re-engineering process.

CASE STUDY: CARRIER AVIATION SUPPORT SYSTEM

Concept of carrier air operations: The carrier is the warship as the role of airbase at sea and operating aircraft is the primary goal. Therefore, the carrier has no means of warfare except self-defense and is the ship performing combat with only embarked combat aircraft. The aircraft carrier is defined in 「Naval Terminology Dictionary」.

"The warship as a role centerpiece of naval task force, having be able to embark, launch and recover the fighter. Having the advantage of approaching quickly to the enemy, launching, attacking and recovering the aircraft and retreating without exposing position at a unseen great distance. Four features of aircraft carrier are high speed (more than 30 kts cruise), long time operation capability and sea keeping, capable of carrying aircraft and independence maintenance capability. As being emphases more offensive than defensive, heading for a large scale for maximizing air operations capability."

Table 1: Carrier classification (by displacement)

Classification	Displacement (ton)	Number of embarked aircraft
Super carrier	More than 70,000	More than 70
Large carrier	50,000~60,000	40~50
Medium carrier	30,000~40,000	30~40
Light carrier	10,000~20,000	Around 20

*: Launch and land method: CATOBAT, STOBAR, STOVL

Now around the advanced nations, 10~12 nations are having or would be having carriers in the world. The carriers are classified in more than 70,000 ton class supercarriers, 50,000~60,000 ton class large carriers, 30,000~40,000 ton class medium carriers and 10,000~20,000 ton class light carriers by size as shown in Table 1; CATOBAR (Catapult Take Off But Arrested Recovery), STOBAR (Short Take Off But Arrested Recovery) and STOVL (Short Take Off and Vertical Landing) by launch and land method; and also multi-mission Carrier (CV), Attack Carrier (CVA), anti-Submarine Carrier (CVS), Escort Carrier (CVE) and so on by mission. Particularly carrier above medium size and CATOBAR method is called "regular carrier" (Hong, 2009).

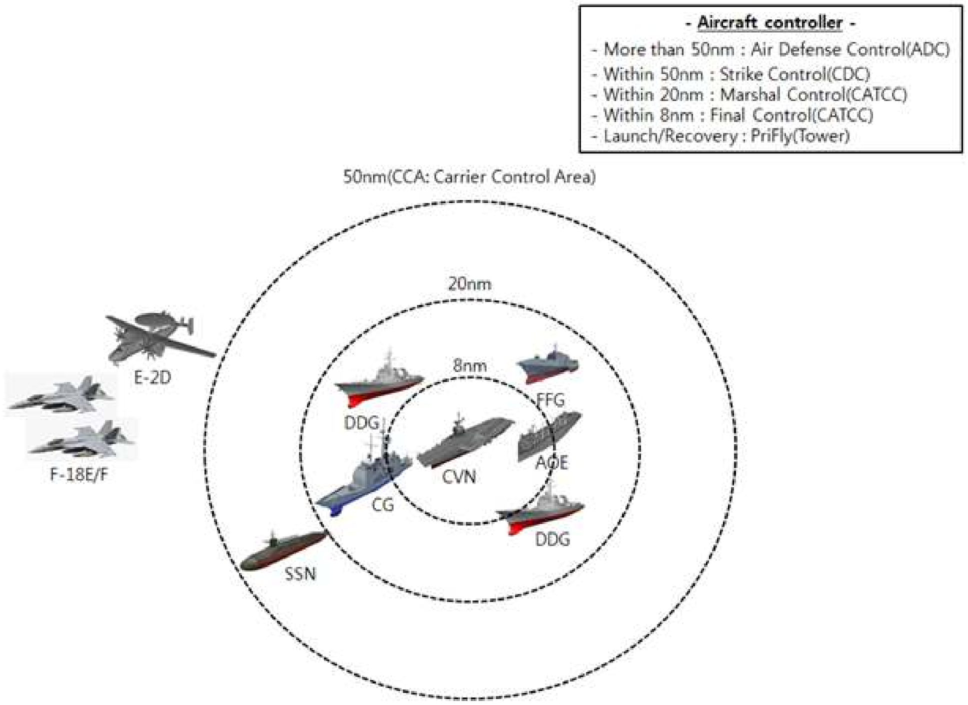

Fig. 3: CSG composition

The aircraft carrier system, Carrier Task Force or CSG (Carrier Strike Group), is large scale system of systems comprised of carrier air wing, AOE, SSN and Escort with carrier itself as the central figure (Fig. 3). In here, aircraft carrier play a role in airbase, air wing play a role in offensive and defensive main combat power, AOE play a role in sustaining support (fuel, ammunition, supply and so forth) and SSN and Escort play a role in defensive mission of CSG (Hermann *et al*., 1991).

In carrier's deck, hundreds of crew and a number of equipment do the Launch, ATC (Air Traffic Control), Recovery and Handling activities by each role and interactions in flight operations steps for supporting harmonious aircraft operations. This is similar to flight operations of ground airbase but more strain and dangerous environment in point of acting a number of aircraft and person simultaneously in small space. Launch is taking off aircraft activity using catapult or ski-jump and ATC is controlling launch and recovery or guiding airborne aircraft activities using communication nets. Recovery is landing aircraft activity from its mission using arresting gear or by vertical landing method and handling is arming/de-arming, refueling, equipment fitting/unfitting, freight loading/unloading, moving, maintenance and so on activities in flight deck or hangar deck. Aircraft carrier is also comprised of subsystems of propulsion system, combat system and navigation system, but in particular the systems collectively called aviation support system related to step-by-step flight activities. This study focused on aviation support system of regular aircraft carrier.

Operational environment: The most important role of carrier is executing support activities such as preparation, launch, ATC, recovery, handling/ maintenance and so on for aircraft's performing mission. Required activities for operating aircraft on board carrier is similar to activities airbase on land, but it is important operating carrier itself and air wing systematically in space no more than 20% of land airbase. Carrier provide control of all kinds systems or equipment and movement required for operating aircraft and aircraft of each squadron under air wing plan, execute, review missions with supporting carrier. On the flight deck repeating this activities every day, getting entangled tens of aircraft and equipment, hundreds of crew, jet fuel and arming, an aircraft is launch and recovery every minute and about 200 sorties mission execute mission in a day. In these on board, a few seconds and several cm of error is that ultimately led to a huge disaster. Carrier as a warship and air wing is systemic and culturally very foreign organizations that are each other. Mutually reinforcing and buffer gave them tours of interaction between these disparate parts to give the carrier aviation support system and organization operating the system of carrier air department.

Concept of operations carrier aviation support system: Carrier aviation support system is system of systems integrated into systems required to support mission in flight steps and this system is in charge of air department under carrier.

Operational scenario: Carrier aviation support system is to ready and launch aircraft according to received flight plan, control aircraft during launch and recovery or airborne, recover aircraft completed mission, refuel and rearm returned aircraft and then repeat this activities for performing other mission. General scenario description is as follows:

- Carrier air wing make out flight plan a day.
- Air Ops decides launch/recovery time as follows flight plan and CATCC, Tower and LSO control aircraft.
- Aircraft ended maintenance in hangar deck is towed to elevator by towing car and moved to flight deck by elevator.
- The aircraft refuel and arm in flight deck.
- The aircraft, ready to flight, is shot out.
- The aircraft, shot out, is controlled initially by CDC (Combat Direction Center) and perform intercept mission by controlling air defense commander.
- The aircraft, completed mission, recover by controlling CATCC, Tower.
- The recovered aircraft is rearmed/refueled for next mission or if no further mission ended mission moving to hangar deck by elevator.

Operational requirements: Being drew out requirements of launch, ATC, recovery and handling systems as follows from missions and operational scenarios of carrier aviation system:

- Aviation system has to functions as independent system installed in carrier.
- Carrier-air wing-aviation support system have to exchange information and data by systematic interactions each other.
- All elements have to hold in common position and state in real time about aircraft, support equipment and person in flight deck and hangar deck.
- ATC system has to aware situation in real time about all aircraft in the air or on the flight deck.
- Communication network always has to possess all primary/secondary.
- Recovery system should be able to utilize all options of approach.
- Recovery and ATC systems have to prepare for bolter.
- Handling system has to grasp all towing car and person.
- All systems have to simultaneous act partially. And so on. There are requirements.

Systems composition: Carrier aviation support system is comprised of launch, ATC, recovery, handling

Fig. 4: Composition of carrier aviation support system

systems. The launch system launch aircraft on flight deck being comprised catapult and JBD (Jet Blast Deflector) as shown in Fig. 4. The ATC system control and monitor interval of launch/recovery and airborne aircraft being composed of all kinds of communication system and ATC radar. The recovery system decides approach method and then stops recovered aircraft on flight deck being comprised arresting gear, ICLS (Instrument Carrier Landing System), ACLS (Automatic Carrier Landing System), OLS (Optical Landing System) and JPALS (Joint Precision Approach and Landing System). The handling system takes part in movement, arming/de-arming, refuel, mission equipment installing/removing and maintenance aircraft being composed of towing car, jet fuel refueling equipment and arming equipment.

Context analysis: Identifying carrier aviation support system an object system and the boundaries of surrounding external environment (system) and then showing up input and output factors of object system with context diagram. The context has relations with system and interfaces exchanging information and data each other as shown in Fig. 5. The purpose of analyzing context is to use as a means of acquiring concept about high level of required system and it provides progressively developed references for identifying system interface requirements and input/output data.

The external systems of carrier aviation support system are 5 systems of CSG (Carrier Strike Group), air wing, carrier and aviation support system and it should be composed interfaces with 5 external systems.

Developing architecture using DoDAF: Being began at defining mission requirements, architecture was developed using DoDAF and each outputs was modeled with CASE CORE. Miguel *et al*. (2010) noted the method modeling total ship using DoDAF.

DoDAF: Beginning with C4ISR AF at 1996, the DoDAF (Depart of Defense Architecture Framework) was issued initially as DoDAF at 2004 and now the newest version is DoDAF 2.0 with gradually being improved. Benchmarking DoDAF, the ROK MND (Minister of Defense) also issued MNDAF but this study applied DoDAF. The DoDAF made a detailed

Fig. 5: Carrier aviation support system context diagram

Fig. 6: Carrier aviation support operational scenario

explanation of standard views acquiring various systems views. This outputs are utilized for developing weapon systems acquisition document such as ICD (Initial Capability Document) and CDD (Capability Development Document). In the U.S. Acquisition Guidance, it makes a note of ICD containing OV-1 and CDD containing AV-1, OV-1, 2, 4, 5, 6c, SV-2, 4, 5, 6, TV-1.

Architecture outputs: As DoDAF, architecture outputs was comprised of All View, Operational View, System View, Technical View in version 1.5 so far and added Capability View, Service View and so on, however, this study developed outputs AV-1, OV-1, 2, 4, 5, 6c. Before developing architecture outputs, making out operational concept detailed scenarios as a statement form and making out the scenarios as a template for identifying operational node activities. Figure 6 is the scenario a statement form and the scenario a template form being converted.

AV-1 overview and summary information: It identified carrier aviation support system and described a purpose and range of architecture making out a text form.

OV-1 high level operational concept graphic: It provided highest level operational views of systems provided in architecture.

OV-2 operational node connectivity description: Node, Architecture element generating, consuming and processing data, that is, it presented exchanging information among operational nodes performing mission or role.

OV-4 organizational relationships chart: It presented hierarchical organization relations.

OV-5 operational activity model: It classified total 44 activities from highest 0 to 3-level and presented IDEF0 and N2 Chart based on these activities.

OV-6c operational state transition description: It presented relations with aviation support system in steps performing mission and presented eFFBD.

Up to now, it makes out architectural outputs as text and diagram types required object/range and operational concept of system, relations among nodes identifying node, activity and relations from operational scenario.

CONCLUSION

The aircraft carrier is the warship operating aircraft as a main object, hence ship and aircraft unit on board should play an active role as single unit and large system so that they could display effective combat power without safety accident. For that reason, it needs to be set up carrier aviation support system for effective air operations on board. In this study, making up architecture of regular aircraft carrier but if modifying architectural outputs it could be apply to light carrier or helicopter carrier.

In this view, this study was made up operational scenario applying systems approach in concept level of carrier aviation support system and drew out operational requirements and presented architecture using DoDAF and CORE tool.

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