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# Development of data analysis tool for combat system integration

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**ABSTRACT:** System integration is an important element for the construction of naval combat ships. In particular, because impeccable combat system integration together with the sensors and weapons can ensure the combat capability and survivability of the ship, the integrated performance of the combat system should be verified and validated whether or not it fulfills the requirements of the end user. In order to conduct systematic verification and validation, a data analysis tool is requisite. This paper suggests the Data Extraction, Recording and Analysis Tool (DERAT) for the data analysis of the integrated performance of the combat system, including the functional definition, architecture and effectiveness of the DERAT by presenting the test results.

*KEY WORDS:* Combat system integration; Systems engineering; System integration; DERAT; Verification and validation; Integrated performance.

# INTRODUCTION

ROK Navy has been building many kinds of combat ship together with a newly developed combat system for the last three decades. A combat system enables a commanding officer to make the right decision by providing the integrated capability. However, as system integration is an exceptionally complicated and complex process, a data analysis tool is required to confirm the integrated performance of the combat system, which should be verified and validated whether or not it fulfills the requirements of the end user. Kumaraswamy (2002) used Failure Reporting, Analysis and Corrective Action System (FRACAS) for the data analysis. However FRACAS was an effective analysis tool to keep track and eliminate failures identified during the prototype flight testing of the Advanced Light Helicopter, it seems to be restricted to prototype flight test. Thus, this paper suggests the DERAT which is developed to analyze the data for the combat system integration, and verify and validate its integrated performance at the system level of newly developed combat system. Furthermore, this paper attempts to confirm the effectiveness of the DERAT by presenting some test results.

# COMBAT SYSTEM DEVELOPMENT PROCESS

The development of a combat system includes not only the combat system itself, but also its full integration with the sensors and weapons to create an integrated performance. Fig. 1 shows the typical Vee model (INCOSE, 2007) which was used to develop the Korean Destroyer Combat System (KDCOM). The stakeholders defined the system requirement based upon those of the Korea Navy. They then developed hardware and software reflecting the definition of the system requirement and the integrated performance was verified and validated through a hierarchical integration process. In general, an enormous amount of data analysis is required to integrate a combat system with various sensors and weapons. Thus, a specialized analysis tool is

Corresponding author: Seung-Chun Shin e-mail: scshin975@snu.ac.kr required to test and evaluate the integrated performance at the system level. This paper suggests the DERAT, which is a suitable solution for a developer who needs to develop a combat system and specialized analysis tool simultaneously.



Fig. 1 Vee model for the KDCOM development.

## DERAT

### Requirement

#### Capability of data extraction, recording and analysis

The data extraction needs to capture not only the individual equipment data, but also the interface data based upon the interface control document. During data extraction, care must be taken to avoid impedance mismatches to ensure that the original signal waveform is not disturbed, because when the DERAT connects to the original cable, the impedance might be changed and the original performance could be influenced. Besides, the DERAT should be compatible with the various interface requirements of the many sensors and weapons. The extracted data should be recorded in a computer for data analysis. In order to analyze the data, the programming of the message description language which identifies and describes the recorded data is essential. Furthermore, the DERAT should be able to convert the data types from one unit to another to allow an alignment of the data from the different subsystems.

## Data display

The DERAT should provide the analyzed data to be output in different display formats, so that the test results can be easily understood by the stakeholders. The analyzed data should be easily translated to other formats for export to other tools.

## ARCHITECTURE

The architecture of the DERAT is defined reflecting the design synthesis process (Min and Kwon, 2004). Fig. 2 shows the architecture of the DERAT.



Fig. 2 Architecture of the DERAT.

Fig. 3 shows the interface diagram between the DERAT and GFEs which explains the types of interface and the data that needs to be extracted and analyzed.

- Global Position System (GPS) data: RS422
- Gyro data: RS422
- Weapon's bearing/range/alignment data: NTDS A
- Sensor's bearing/range/alignment data: NTDS A or NTDS D
- Interface Data between the combat system and the GFEs: Ethernet



Fig. 3 Interface diagram between the DERAT and GFEs.

#### DEVELOPMENT OF THE DERAT

#### Message description language programming

A message description language is used for the data description and contains several message description include. It converts the raw data format into the interpreted data format used by the DERAT. An example of the message description language programming is given below.

\* FILE :000.mdl \* Archive : \* \* Project : 000 \* Revision : 1.00 \* Date : 04.01.2010 \* \* Description : \* Comment : \* \_\_\*/ #include 000 GPS.mdi #include 000 SAM.mdi #include 000 LRR.mdi block file header info [file info] ł const [start time] : "now" const \_ [msg\_time\_type] \_: "timeofday" const [msg\_time\_pos] : 1 } while(!eof) { channel nb [cnl nb] "hex" unit bend 8 *switch (\$channel nb)* { *case* 0x10 : block xxx xxx { const channel nb "hex"\$channel nb block ref [block ref] unit bend 24 reception time [time] "ms" unit bend 32 block length "word"unit bend 16 \_jump\_\_unit bend 0:16 msg\_nb\_"hex" unit bcross 16 *jump unit bend* 0:-32 table xxx xxx channel(\$msg nb) } *case* 0*x*11 : block yyy\_yyy ł } *case* 0x12 : block zzz zzz

#### **Configuration of the DERAT**

The DERAT consists of 5 components, including a Data Recording Computer (DRC), a Portable Workstation (PWS), a Data Extraction Box (DEB), a Y-Cable Tap, and a Connector Panel. Fig. 4 shows the basic configuration of the DERAT. All of the sensors and weapons are connected to the CSDB through the Bus Terminal Server (BTS) and interfaced together through the CSDB. Consequently, the rational data extraction position is a certain point between the GFE and the BTS of the GFE. Regarding the characteristics of the interface, various methods of data extraction were implemented, i.e. the Y-Cable Tap for NTDS A, the DEB for NTDS D and RS 422. The DEBs were designed to reflect the characteristics of each interface and connected to the DRC through the connector panel. The DRCs, the DEBs and the connector panels were properly installed on the ship regarding the position of the GFE, and the PWS was connected to the DRC #1 for the data analysis.



BTS Bus Terminal Server

Fig. 4 Basic configuration of DERAT.

## NTDS A data extraction

The US DoD (1998) defined the NTDS A interface as a parallel data transfer. The normal NTDS A interface consists of two channels, an input channel and an output channel. Therefore, the NTDS A interfaces were tapped by Y-cable taps. One line of



Fig. 5 NTDS-A data extraction.

the Y-cable was connected to the GFE and the other line was connected to the DRC to provide the data for recording, as illustrated in Fig. 5.

#### NTDS D data extraction

The US DoD (1998) defined the NTDS D interface as an asynchronous serial data transfer. For two-way communication, two lines of communication are necessary. One line is the source line which is from the main equipment to the external function, and the other line is the sink line which is from the external function to the main equipment. Fig. 6 shows the DEB installation for the NTDS D data extraction.



Fig. 6 NTDS-D data extraction.

Because no commercial-off-the-shelf components exist for passive tapping of a serial NTDS interface, the design of a dedicated Peripheral component interface Mezzanine Card (PMC) was necessary. In order to extract the serial NTDS D data without disturbing the original signal waveform, impedance matching is essential. Fig. 7 shows the PMC NTDS D cabling for connecting the tap to the original cable. Cables A and B are the original cables and Cable C is for tapping. In order to maintain constant impedance from the source to the sink, the tap should have a high impedance and the length of Cable C should be as short as possible.



Fig. 7 PMC NTDS-D cabling.

As illustrated in Fig. 8, when a wave travels from the source along the line, it hits a boundary and some of the wave reflects back, while some of it continues to move forward. Assuming that the impedance of the source side is  $Z_1$  and that of the load side is  $Z_2$  at the boundary, Hayt (1989) defined the reflection coefficient  $\Gamma$  as follows:



$$\Gamma = \frac{Z_2 - Z_1}{Z_1 + Z_2}$$
(1)

To obtain the original signal waveform without any disturbance at the end of the line, the reflection coefficient  $\Gamma$  should be as small as possible. Thus, regarding Fig. 6, in order to obtain the original signal waveform without any disturbance, the reflection coefficient  $\Gamma$  induced by the Tap should be as small as possible.

$$\Gamma = \frac{Z_0 - Z}{Z + Z_0} \tag{2}$$

In order to calculate the reflection coefficient  $\Gamma$  induced by the Tap, the impedance Z at the tap point has to be calculated.

$$Z = \frac{Z_1 Z_2}{Z_1 + Z_2}$$
(3)

Regarding Fig. 6,  $Z_1$  is  $Z_0$  which is 75 *ohms* for the NTDS D interface, and  $Z_2$  is the impedance of the input circuit itself, which has a resulting input impedance of 20 *kohms*. Thus, substituting  $Z_0 = 75$  *ohms* and  $Z_{input circuit} = 20$  *kohms* into Eqn (3), the impedance Z at the tap point is as follows.

$$Z = \frac{Z_0 Z_{input circuit}}{Z_0 + Z_{input circuit}} = \frac{75 \times 20000}{75 + 20000} = 74.72 ohms$$

Substituting  $Z_0 = 75$  ohms and Z = 74.72 ohms into Eqn (2), the reflection coefficient  $\Gamma$  induced by the Tap is as follows.

$$\Gamma = \frac{Z_0 - Z}{Z + Z_0} = \frac{75 - 74.72}{74.72 + 75} = 0.18\%$$

Thus, it is negligible and no signal influence was observed.

#### RS 422 data extraction

EIA (1994) defined the RS 422 as a full duplex serial data transfer. Fig. 9 shows the DEB installation for the RS 422 data extraction. In order to extract the RS 422 data, the DEB was connected to the RS 422 data channel. The DEB has three connectors for the data-input, data-output and data-output to the DRC. The input and output for each data channel were directly connected inside the DEB. Parallel to the data line were galvanic couplers transmitting the data to the RS 422 amplifier. The galvanic couplers isolate the operational and recording data.



Fig. 9 RS 422 data extraction.

## Ethernet data extraction

IEEE (1990) standardized the Ethernet as IEEE 802.3. In order to extract the Ethernet data, the DEB was connected to the CSDB using the existing BTS tap which was used for the GFE connection to the CSDB. Fig. 10 shows the DEB installation for the Ethernet data extraction. The original configuration of the KDCOM adopted two CSDBs for the sake of system redundancy. Therefore, the DEB connection to the CSDB was made through two existing bus taps. The data was extracted using the Network Interface Card installed in the DEB. Some of the equipment used a 10Base2 signal and the others used a 10Base T signal. For the analysis, the 10Base2 signal was converted to the 10BaseT signal using the Attachment Unit Interface Transceiver, which was installed in the Network Interface Card in accordance with IEEE 802.3.



Fig. 10 Ethernet data extraction.

### TEST RESULT OF THE DERAT

## Land Based Test Site (LBTS) test

Fig. 11 shows the simulated environment used for the LBTS test. A simulated environment was established reflecting the basic configuration of the KDCOM. Simulators were used for the test instead of real sensors and weapons.

Fig. 12 shows the block diagram of the message test environment used to verify the functionality of the DERAT. The basic functions of the DERAT including MDL validation, Non-Interference, Power-On & Initialization, On-line Display, DRC Control, Data Extraction, Data Recording, and Data Analysis were fully tested and demonstrated. In particular, the Non-Interference Test was performed for each interface type in order to confirm that the extraction of data from the external interfaces did not interfere with the interfaces tapped by the DERAT. The test results showed that no interference was observed due to the DERAT. After the completion of the LBTS test, the DERAT was installed on a Korean Destroyer to conduct the Onboard test, in accordance with Fig. 13. The result of the On-board test is described below.



Fig. 11 Simulated environment for the LBTS test.



Fig. 12 Block diagram of message test environment.

# **ON-BOARD TEST**

## Installation of the DERAT

Fig. 13 shows an example of the installation of the DERAT for the data analysis of the AAW scenarios. Although a number of scenarios concerned with Anti Air Warfare, Anti Surface Warfare, and Anti Sub-Surface Warfare were con-

ducted, only some of the analysis results of the Anti Air Warfare scenario will be presented as an example of the tests performed in this study.



Fig. 13 Example of installation of the DERAT for AAW analysis.

#### **Test procedure**

The required operational capabilities were defined and the test scenarios were validated and conducted. During the test, the individual equipment data and interface data were extracted and analyzed. The operational authorities and technical authorities were provided with the analyzed data for review. If shortfalls or errors were identified, they were sent back to find a solution as illustrated in Fig. 14.



Fig. 14 Test procedure.

## **Test Result**

## Data display & analysis

The following 3 figures show the analysis results of one of the AAW scenarios. As illustrated in Fig. 15, the PPI displays that the Air Search Radar tracks a red colored hostile target designated with the track number 65, which is also designated with identification number 52 in Fig. 16, and the Combat System assigns the Surface-to-Air missile to engage with track number 65.



Fig. 15 AAW engagement status.

Fig. 16 shows the track list from the data file sorted by identification. This list shows that the Surface-to-Air missile is assigned to engage with track number 65 which is designated with identification number 52.

Flags         Id         Cat         Starttime         Endtime         Lifetime         Count           n         12         Air_Track_Report_Buffer_LRR_CSDB         07:27:41.767         07:28:57.776          17           n         13         Air_Track_Report_Buffer_LRR_CSDB         07:27:41.767         07:28:59.748          17           n         13         Air_Track_Report_Buffer_LRR_CSDB         07:28:45.25         07:29:09.453          44           n         17         Air_Track_Report_Buffer_LRR_CSDB         07:27:44.622         07:29:00.453          14           n         17         Air_Track_Report_ANSys2         07:27:40.636         07:09:00.456          14           n         22         Air_Track_Report_ANSys2         07:27:40.636         07:09:00.326         07:09:00.020         0           n         24         Air_Track_Report_ANSys2         07:27:30.356         07:29:00.923          17           n         33         Air_Track_Report_ANSys2         07:27:29.356         07:29:00.923          17           n         33         Air_Track_Report_ANSys2         07:29:01.536          17           n <td< th=""><th></th><th>A</th><th>le</th><th>Visib</th><th>Selected</th><th>icks</th><th>m Tra</th><th>Syste</th></td<>		A	le	Visib	Selected	icks	m Tra	Syste
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n •       22       Air_Track_Report_MNSys2       07:27:41.611       07:27:41.611       0.000000       0         n 24       Air_Track_Report_MNSys2       07:28:23.382       07:28:57.956        7         n 31       Air_Track_Report_MNSys2       07:28:23.382       07:28:57.956        18         n 33       Air_Track_Report_MNSys2       07:27:39.856       07:28:59.953        18         n 33       Air_Track_Report_MNSys2       07:27:39.856       07:28:59.956        18         n 33       Air_Track_Report_MNSys2       07:27:51.28       07:28:59.956        15         n 34       Air_Track_Report_LREPCIDE       07:27:51.215       07:28:59.925        15         n 40       Air_Track_Report_MNSys2       07:27:30.956       07:29:00.356        12         n 41       Air_Track_Report_LREPCIDE       07:29:01.333       07:29:00.356        12         n 41       Air_Track_Report_MNSys2       07:27:40.756       07:29:00.956        18         n 47       Air_Track_Report_MNSys2       07:27:40.756       07:29:00.953        18         n 54       Air_Track_Report_MNSys2       07:27:40.750       07:29:00.953 </td <td>5</td> <td>000000.</td> <td>0,000</td> <td>7:27:40.626</td> <td>07:27:40.626 07</td> <td>Air_Track_Report_Buffer_LRR_CSDB</td> <td>22</td> <td>n •</td>	5	000000.	0,000	7:27:40.626	07:27:40.626 07	Air_Track_Report_Buffer_LRR_CSDB	22	n •
n         24         Air_Track_Report_Buffer_LRR_CSDB         07:28:29,362         07:28:57,956          77           n         24         Air_Track_Report_BNSg2         07:28:39,362         07:28:59,052          78           n         31         Air_Track_Report_BNSg2         07:27:39,056         07:28:59,052          18           n         31         Air_Track_Report_Buffer_LRR_CSDB         07:27:51,228         07:28:59,058          15           n         33         Air_Track_Report_Buffer_LRR_CSDB         07:27:51,228         07:28:59,038          15           n         33         Air_Track_Report_Buffer_LRR_CSDB         07:27:51,228         07:29:00,556          15           n         40         Air_Track_Report_Buffer_LRR_CSDB         07:27:30,756         07:29:00,556          18           n         41         Air_Track_Report_Buffer_LRR_CSDB         07:27:30,756         07:29:00,503          18           n         47         Air_Track_Report_Buffer_LRR_CSDB         07:27:43,627         07:29:00,903          19           n         41         Air_Track_Report_Buffer_LRR_CSDB         07:29:01,905          19	5	0.000000	0.000	7:27:41.611	07:27:41.611 07	Air_Track_Report_ANSys2	22	n •
n         24         Air_Track_Report_MNSys2         07:28:30,356         07:28:58,923          77           n         31         Air_Track_Report_MNSys2         07:27:39,856         07:29:09,828          18           n         31         Air_Track_Report_MNSys2         07:27:39,856         07:29:09,828          18           n         31         Air_Track_Report_Buffer_LRR_CSDB         07:27:151,228         07:28:59,325          15           n         33         Air_Track_Report_Buffer_LRR_CSDB         07:29:10,328          12           n         40         Air_Track_Report_Buffer_LRR_CSDB         07:29:10,336          12           n         41         Air_Track_Report_ANSys2         07:29:10,336          18           n         41         Air_Track_Report_ANSys2         07:29:10,356          18           n         47         Air_Track_Report_ANSys2         07:29:10,356         07:29:10,503          18           n         47         Air_Track_Report_ANSys2         07:29:17,936         07:29:10,9316          17           n         58         Besignation_ASHICSB         07:29:17,932 <t< td=""><td>7</td><td></td><td>-</td><td>7:28:57.956</td><td>07:28:29.362 07</td><td>Air_Track_Report_Buffer_LRR_CSDB</td><td>24</td><td>n</td></t<>	7		-	7:28:57.956	07:28:29.362 07	Air_Track_Report_Buffer_LRR_CSDB	24	n
n         31         Air_Track_Report_ANSys2         07:27:39.856         07:29:00.628          18           n         31         Air_Track_Report_Buffer_LRR_CSDB         07:27:43.627         07:28:59.836          17           n         33         Air_Track_Report_Buffer_LRR_CSDB         07:27:43.627         07:28:59.836          15           n         33         Air_Track_Report_Buffer_LRR_CSDB         07:28:19.030         07:28:59.923          15           n         40         Air_Track_Report_Buffer_LRR_CSDB         07:28:09.133         07:29:00.336          12           n         40         Air_Track_Report_Buffer_LRR_CSDB         07:28:09.133         07:29:00.336          12           n         41         Air_Track_Report_Buffer_LRR_CSDB         07:22:39.756         07:29:00.536          18           n         47         Air_Track_Report_ANSys2         07:27:23.856         07:29:00.903          18           n         47         Air_Track_Report_Buffer_LRR_CSDB         07:29:10.232         07:29:10.232          18           n         47         Air_Track_Report_Buffer_LRR_CSDB         07:29:10.232          17			-	7:28:58.923	07:28:30.356 07	Air_Track_Report_ANSys2	24	n
n         31         Air_Track_Report_Buffer_LRR_CSDB         07:27:43.627         07:28:59.636          17           n         33         Air_Track_Report_Buffer_LRR_CSDB         07:27:51.228         07:28:59.636          15           n         35         Air_Track_Report_Buffer_LRR_CSDB         07:27:51.228         07:28:59.636          15           n         40         Air_Track_Report_Buffer_LRR_CSDB         07:28:10.305          12           n         40         Air_Track_Report_Buffer_LRR_CSDB         07:28:09.133         07:29:00.356          12           n         41         Air_Track_Report_Buffer_LRR_CSDB         07:27:40.736         07:29:00.536          18           n         41         Air_Track_Report_Buffer_LRR_CSDB         07:27:40.736         07:29:00.903          18           n         47         Air_Track_Report_Buffer_LRR_CSDB         07:29:50.417          20           n         52         Destoration_BHI CSDB         07:29:57.993         07:29:00.448          20           n         54         Air_Track_Report_Buffer_LRCSDB         07:29:41.767         07:28:59.748          17	3		-	7:29:00.628	07:27:39.856 07	Air_Track_Report_ANSys2	31	n
n         33         Air_Track_Report_Buffer_LRR_CSDB         07:27:51,228         07:28:57,366          15           n         33         Air_Track_Report_ANSys2         07:27:52,155         07:28:59,325          15           n         40         Air_Track_Report_ANSys2         07:22:105         07:29:100,356          12           n         40         Air_Track_Report_ANSys2         07:29:00,133         07:29:00,356          12           n         40         Air_Track_Report_ANSys2         07:27:30,756         07:29:00,356          12           n         41         Air_Track_Report_ANSys2         07:27:30,756         07:29:00,503          18           n         47         Air_Track_Report_ANSys2         07:27:30,856         07:29:00,803          18           n         47         Air_Track_Report_Buffer_LRR_CSDB         07:29:00,736         07:29:00,403          18           n         47         Air_Track_Report_Buffer_LRR_CSDB         07:29:10,736          17           n         58         Besignation_RMI_CSDB         07:29:40,738         07:29:50,442          20           n         5	7		-	7:28:59.636	07:27:43.627 07	Air_Track_Report_Buffer_LRR_CSDB	31	n
n         33         Air_Track_Report_ANSys2         07:27:52,195         07:28:58.923          15           n         40         Air_Track_Report_Buffer_LRR_CSDB         07:28:08,150         07:28:00,356          12           n         40         Air_Track_Report_Buffer_LRR_CSDB         07:28:09,150         07:29:00,556          12           n         40         Air_Track_Report_BNSys2         07:29:01,536          12           n         41         Air_Track_Report_BNSys2         07:27:37,56         07:29:00,536          18           n         41         Air_Track_Report_BNSys2         07:27:37,56         07:29:00,536          18           n         47         Air_Track_Report_BNSys2         07:27:37,56         07:29:00,536          18           n         47         Air_Track_Report_BNSys2         07:27:37,56         07:29:00,432          17           n         54         Bir_Track_Report_Buffer_LRR_CSDB         07:29:57,935         07:29:00,442          17           n         54         Air_Track_Report_BNSys2         07:27:42,738         07:29:00,442          17           n         A	5		-	7:28:57.956	07:27:51.228 07	Air_Track_Report_Buffer_LRR_CSDB	33	n
n         40         Air_Track_Report_Buffer_LRR_CSDB         07:28:08.150         07:29:00.356          12           n         40         Air_Track_Report_BNSys2         07:28:09.153         07:29:00.356          12           n         41         Air_Track_Report_BNSys2         07:29:01.756         07:29:00.556          12           n         41         Air_Track_Report_BNSys2         07:27:39.756         07:29:00.536          18           n         41         Air_Track_Report_BNSys2         07:27:40.756         07:29:00.903          18           n         47         Air_Track_Report_BNSys2         07:27:40.756         07:29:00.903          18           n         47         Air_Track_Report_BNSys2         07:27:40.756         07:29:00.903          18           n         47         Air_Track_Report_LRE_CSDB         07:29:57.932         07:29:00.417          20           n         58         Designation_RMI_CSDB         07:29:10.736          17         17           n         54         Air_Track_Report_RNSys2         07:27:40.786         07:29:59.746          17           n	5		-	7:28:58.923	07:27:52.195 07	Air_Track_Report_ANSys2	33	n
n         40         Air_Track_Report_ANSys2         07:28:09.133         07:29:01.328          12           n         44         Air_Track_Report_ANSys2         07:27:39.756         07:29:00.535          18           n         44         Air_Track_Report_ANSys2         07:27:39.756         07:29:00.535          18           n         44         Air_Track_Report_ANSys2         07:27:39.756         07:29:00.503          18           n         47         Air_Track_Report_ANSys2         07:27:39.856         07:29:00.903          18           n         47         Air_Track_Report_Buffer_LRR_CSDB         07:29:07.930         07:29:00.903          18           n         47         Air_Track_Report_Buffer_LRR_CSDB         07:29:07.942          20           n         54         Air_Track_Report_Buffer_LRR_CSDB         07:27:47.80         07:29:00.442          17           n         54         Air_Track_Report_ANSys2         07:27:47.80         07:29:50.776          18           n         104         Air_Track_Report_ANSys2         07:27:47.478         07:29:50.786          17           n <t< td=""><td>2</td><td></td><td>-</td><td>7:29:00.356</td><td>07:28:08.150 07</td><td>Air_Track_Report_Buffer_LRR_CSDB</td><td>40</td><td>n</td></t<>	2		-	7:29:00.356	07:28:08.150 07	Air_Track_Report_Buffer_LRR_CSDB	40	n
n         41         Air_Track_Report_Buffer_LRR_CSDB         07:27:39,756         07:29:00,536          18           n         41         Air_Track_Report_MNSys2         07:27:40,736         07:29:00,536          18           n         47         Air_Track_Report_MNSys2         07:27:40,736         07:29:00,503          18           n         47         Air_Track_Report_MNSys2         07:27:43,627         07:29:00,903          18           n         47         Air_Track_Report_LNSp2         07:27:43,627         07:29:00,903          18           n         52         Designation_RHLCSDB         07:29:10,939         07:29:00,2447          20           n         54         Air_Track_Report_Buffer_LRR_CSDB         07:29:10,2417          17           n         54         Air_Track_Report_Buffer_LRR_CSDB         07:29:10,726          17           n         104         Air_Track_Report_MNSgs2         07:27:40,786         07:29:50,748          17           n         104         Air_Track_Report_MNSgs2         07:27:40,786         07:29:50,966          17           n         104         Air_Tra	21			7:29:01.328	07:28:09.133 07	Air_Track_Report_ANSys2	40	n
n         41         Air_Track_Report_ANSys2         07:27:40.736         07:29:01.503          18           n         47         Air_Track_Report_ANSys2         07:27:39.856         07:29:00.803          18           n         47         Air_Track_Report_Buffer_LRR_CSDB         07:27:39.856         07:29:00.403          18           n         47         Air_Track_Report_Buffer_LRR_CSDB         07:29:17.935         07:29:00.417          20           n         52         Designation_RHLCSDB         07:29:17.935         07:29:00.442          20           n         54         Air_Track_Report_Buffer_LRR_CSDB         07:27:41.767         07:29:57.776          17           n         54         Air_Track_Report_Buffer_LRR_CSDB         07:27:40.786         07:29:59.748          17           n         104         Air_Track_Report_LNSps2         07:27:40.786         07:29:59.046          17           n         104         Air_Track_Report_LNSps2         07:27:40.789         07:29:59.046          17           n         104         Air_Track_Report_LRSCSDB         07:27:40.789         07:29:58.9825          17 </td <td>3</td> <td></td> <td>-</td> <td>7:29:00.536</td> <td>07:27:39.756 07</td> <td>Air_Track_Report_Buffer_LRR_CSDB</td> <td>41</td> <td>n</td>	3		-	7:29:00.536	07:27:39.756 07	Air_Track_Report_Buffer_LRR_CSDB	41	n
n         47         Air_Track_Report_ANSys2         07:27:39.856         07:29:00.903          18           n         47         Air_Track_Report_Buffer_LRR_CSDB         07:27:43.627         07:29:59.816          17           n         52         Destanation_BHI_CSDB         07:29:57.936         07:29:00.412          20           n         54         Berstanation_BHI_CSDB         07:29:457.932         07:29:00.442          20           n         54         Air_Track_Report_Buffer_LRR_CSDB         07:27:41.767         07:29:57.776          17           n         54         Air_Track_Report_Buffer_LRR_CSDB         07:27:42.738         07:29:50.748          17           n         104         Air_Track_Report_Buffer_LRR_CSDB         07:27:41.866         07:28:59.048          17           n         104         Air_Track_Report_Buffer_LRR_CSDB         07:27:41.786         07:28:59.048          17           n         104         Air_Track_Report_Buffer_LRR_CSDB         07:27:41.786         07:28:59.056          17           n         110         Air_Track_Report_Buffer_LRR_CSDB         07:27:42.738         07:28:59.036	<u>, I</u>		-	7:29:01.503	07:27:40.736 07	Air_Track_Report_ANSys2	41	n
n         47         Air_Track_Report_Buffer_LRR_CSDB         07:27:43.627         07:28:59.616          17           n         53         Designation_DMI_CSDB         07:28:57.996         07:28:57.996          20           n         55         Designation_DMI_CSDB         07:28:57.996         07:28:50.2442          20           n         54         Besignation_DMI_CSDB         07:28:57.996         07:28:50.2442          20           n         54         Air_Track_Report_Buffer_LRR_CSDB         07:27:41.767         07:28:57.776          107           n         54         Air_Track_Report_ANSgs2         07:27:41.767         07:28:59.048          107           n         104         Air_Track_Report_Buffer_LRR_CSDB         07:27:41.786         07:28:59.048          117           n         104         Air_Track_Report_Buffer_LRR_CSDB         07:27:41.786         07:28:59.048          127           n         110         Air_Track_Report_Buffer_LRR_CSDB         07:27:41.786         07:28:59.036          117           n         113         Air_Track_Report_Buffer_LRR_CSDB         07:27:42.780         07:28:59.036	5		-	7:29:00.803	07:27:39.856 07	Air_Track_Report_ANSys2	47	n
n         52         Designation_RAH_CSDB         07:28:57.993         07:29:02.417          20           n         53         Designation_RAH_CSDB         07:28:57.993         07:29:02.447          20           n         54         Air_Track_Report_Buffer_LRR_CSDB         07:28:17.993         07:29:02.447          20           n         54         Air_Track_Report_Buffer_LRR_CSDB         07:27:41.767         07:28:59.748          17           n         104         Air_Track_Report_Buffer_LRR_CSDB         07:27:41.866         07:29:01.796          18           n         104         Air_Track_Report_ANSys2         07:27:41.866         07:29:50.948          17           n         104         Air_Track_Report_Buffer_LRR_CSDB         07:27:41.866         07:28:59.936          17           n         110         Air_Track_Report_Buffer_LRR_CSDB         07:27:42.781         07:28:59.935          17           n         113         Air_Track_Report_Buffer_LRR_CSDB         07:27:42.817         07:28:59.936          17           n         113         Air_Track_Report_ANSys2         07:27:42.817         07:28:59.936 <t< td=""><td>7</td><td></td><td>-</td><td>7:28:59.816</td><td>07:27:43.627 07</td><td>Air_Track_Report_Buffer_LRR_CSDB</td><td>47</td><td>n</td></t<>	7		-	7:28:59.816	07:27:43.627 07	Air_Track_Report_Buffer_LRR_CSDB	47	n
n         53         Detrignation_RMLCSDB         07:29:57,332         07:29:02.442          20           n         54         Air_Track_Report_Buffer_LRR_CSDB         07:27:41,787         07:29:57,776          17           n         54         Air_Track_Report_Buffer_LRR_CSDB         07:27:42,738         07:29:50,748          17           n         104         Air_Track_Report_Buffer_LRR_CSDB         07:27:40,886         07:29:50,748          18           n         104         Air_Track_Report_Buffer_LRR_CSDB         07:27:41,866         07:29:59,048          17           n         104         Air_Track_Report_Buffer_LRR_CSDB         07:27:41,767         07:28:57,956          17           n         110         Air_Track_Report_Buffer_LRR_CSDB         07:27:42,738         07:28:59,936          17           n         113         Air_Track_Report_Buffer_LRR_CSDB         07:27:42,817         07:28:59,936          17           n         113         Air_Track_Report_Buffer_LRR_CSDB         07:27:42,810         07:29:00,035          17           n         113         Air_Track_Report_Buffer_LRR_CSDB         07:27:42,810         07:29:00,035	<b>.</b>		-	7:29:02.417	07:28:57.903 07	Designation_RAM_CSDB	52	n
n         54         Air_Track_Report_Buffer_LRR_CSDB         07:27:41.767         07:28:57.776          17           n         54         Air_Track_Report_BNSg2         07:27:42.738         07:25:59.748          17           n         104         Air_Track_Report_BNSg2         07:27:42.738         07:28:59.048          18           n         104         Air_Track_Report_Buffer_LRR_CSDB         07:27:41.866         07:28:59.048          17           n         104         Air_Track_Report_Buffer_LRR_CSDB         07:27:41.787         07:28:59.048          17           n         100         Air_Track_Report_Buffer_LRR_CSDB         07:27:41.787         07:28:59.048          17           n         110         Air_Track_Report_Buffer_LRR_CSDB         07:27:42.780         07:28:59.036          17           n         113         Air_Track_Report_Buffer_LRR_CSDB         07:27:42.817         07:28:59.036          17           n         113         Air_Track_Report_Buffer_LRR_CSDB         07:27:42.817         07:28:09.036          17           n         113         Air_Track_Report_Buffer_LRR_CSDB         07:27:42.817         07:28:09.036	51		-	7:29:02.442	07:28:57.932 07	Designation_RAM_CSDB	53	n.
n         54         Air_Track_Report_ANSys2         07:27:42.738         07:28:59.748          17           n         104         Air_Track_Report_Buffer_LRR_CSDB         07:27:40.836         07:29:01.796          18           n         104         Air_Track_Report_Buffer_LRR_CSDB         07:27:41.866         07:28:59.048          17           n         104         Air_Track_Report_Buffer_LRR_CSDB         07:27:41.866         07:28:59.048          17           n         110         Air_Track_Report_Buffer_LRR_CSDB         07:27:42.788         07:28:59.036          17           n         113         Air_Track_Report_Buffer_LRR_CSDB         07:27:42.817         07:28:59.036          17           n         113         Air_Track_Report_ANSys2         07:27:42.817         07:28:59.036          17           n         113         Air_Track_Report_ANSys2         07:27:42.817         07:28:00.035          17           n         114         Air_Track_Report_ANSys2         07:27:42.818         07:29:00.035          17           n         114         Air_Track_Report_ANSys2         07:27:41.580         07:29:00.035 <t< td=""><td>7</td><td></td><td>-</td><td>7:28:57.776</td><td>07:27:41.767 07</td><td>Air_Track_Report_Buffer_LRR_CSDB</td><td>54</td><td>n</td></t<>	7		-	7:28:57.776	07:27:41.767 07	Air_Track_Report_Buffer_LRR_CSDB	54	n
n         104         Air_Track_Report_Buffer_LRR_CSDB         07:27:40.896         07:29:01.796          18           n         104         Air_Track_Report_BNSg2         07:27:41.886         07:28:59.048          17           n         110         Air_Track_Report_BNSg2         07:27:41.886         07:28:59.056          17           n         110         Air_Track_Report_BNSg2         07:27:41.780         07:28:59.356          17           n         113         Air_Track_Report_BNSg2         07:27:42.781         07:28:59.036          17           n         113         Air_Track_Report_BNSg2         07:27:42.817         07:28:59.036          17           n         113         Air_Track_Report_BNSg2         07:27:42.817         07:28:59.036          17           n         113         Air_Track_Report_BNSg2         07:27:42.810         07:29:00.030          17           n         114         Air_Track_Report_BNSg2         07:27:42.810         07:29:00.030          17           n         114         Air_Track_Report_BNSg2         07:29:00.200          17	21		-	7:28:58.748	07:27:42.738 07	Air_Track_Report_ANSys2	54	n
n         104         Air_Track_Report_ANSys2         07:27:41.866         07:28:59.048          17           n         110         Air_Track_Report_Buffer_LRR_CSDB         07:27:41.787         07:28:57.956          17           n         110         Air_Track_Report_Buffer_LRR_CSDB         07:27:42.738         07:28:59.958          17           n         113         Air_Track_Report_Buffer_LRR_CSDB         07:27:42.817         07:28:59.938          17           n         113         Air_Track_Report_Buffer_LRR_CSDB         07:27:42.817         07:28:59.938          17           n         113         Air_Track_Report_Buffer_LRR_CSDB         07:27:42.817         07:28:50.9036          17           n         114         Air_Track_Report_Buffer_LRR_CSDB         07:27:42.817         07:28:50.9036          17           n         114         Air_Track_Report_Buffer_LRR_CSDB         07:27:41.580         07:29:00.9035          17           n         114         Air_Track_Report_Buffer_LRR_CSDB         07:27:41.580         07:29:00.9035          17	3		-	7:29:01.796	07:27:40.896 07	Air_Track_Report_Buffer_LRR_CSDB	104	n
n         110         Air_Track_Report_Buffer_LRR_CSDB         07:27:41.767         07:28:57.956          17           n         110         Air_Track_Report_RNSys2         07:27:42.738         07:28:58.923          17           n         113         Air_Track_Report_Buffer_LRR_CSDB         07:27:42.837         07:28:59.036          17           n         113         Air_Track_Report_Buffer_LRR_CSDB         07:27:42.837         07:28:59.036          17           n         113         Air_Track_Report_ANSys2         07:27:43.808         07:29:00.003          17           n         114         Air_Track_Report_Buffer_LBR_CSDB         07:27:41.587         07:29:00.003          17			-	7:28:58.048	07:27:41.866 07	Air_Track_Report_ANSys2	104	n
n         110         Air_Track_Report_ANSys2         07:27:42.738         07:28:58.923          17           n         113         Air_Track_Report_Buffer_LRR_CSDB         07:27:42.817         07:28:59.036          17           n         113         Air_Track_Report_ANSys2         07:27:43.808         07:29:00.003          17           n         113         Air_Track_Report_ANSys2         07:27:43.808         07:29:00.003          17           n         114         Air_Track_Report_Report_BIFGRE_IDE         07:27:41.527         07:29:00.003          17	7		-	7:28:57.956	07:27:41.767 07	Air_Track_Report_Buffer_LRR_CSDB	110	n
n         113         Air_Track_Report_Buffer_LRR_CSDB         07:27:42.817         07:28:59.036          17           n         113         Air_Track_Report_ANSys2         07:27:43.808         07:23:00.003          17           n         114         Air_Track_Report_ANSys2         07:27:43.808         07:29:00.003          17           n         114         Air_Track_Report_BNSE         07:27:41.587         07:29:00.272          17	- I		-	7:28:58.923	07:27:42.738 07	Air_Track_Report_ANSys2	110	n
n 113 Rir_Track_Report_RNSys2 07:27:43,808 07:29:00.003 17	7		-	7:28:59.036	07:27:42.817 07	Air_Track_Report_Buffer_LRR_CSDB	113	n
p 114 Bin Track Percent Buffer LPR CSBR 07+27+41 587 07-29+02 770 19			-	7:29:00.003	07:27:43.808 07	Air_Track_Report_ANSys2	113	n
10 11 11 11 UNA_ 10 00 0 0 00 0 0 0 0 0 0 0 0 0 0 0 0 0	3		-	7:29:02.336	07:27:41.587 07	Air_Track_Report_Buffer_LRR_CSDB	114	n

Fig. 16 Track list from data file sorted by ID.



Fig. 17 shows the multi sensor track data within the particular time frame. While the Long Range Air search Radar tracked the above track number 65, the initial contact was made by the Medium Range Air search Radar at 22.5 km.

Fig. 17 LRR track shown with first acquisition by MRR.

The above figures provide the data about the same target or in different formats. These data were very useful for the later analysis. For example, if the above engagement fails due to unknown faults, the technical authorities can review the analysis result of the individual equipment data and the interface data recorded at that time, identify the reason for the failure and then find the solution.

#### Alignment check

All of the sensors and weapons on-board should be aligned perfectly to ensure a precise engagement. In the case of misalignment, the failure of the engagement is inevitable due to the inaccurate data which causes the error. If the error is a bias error that remains constant in magnitude for all observations, it is relatively easy to correct it. If inherently unpredictable random errors are observed, the equipment should be radically corrected. Actually, a number of test runs were conducted to check the alignment status of the sensors and weapons. Figs. 18, 19 and 20 show examples of the analysis results of the ESM bearing data compared with the real target bearing data provided by the MW 08 Radar through the test run. According to the analysis result,



a bias error of the ESM bearing which was an average of 4.32° less than the real target bearing was observed, was corrected by the gyro supplier and no further errors were observed.

#### Fault detection

Fig. 21 shows an example of the fault detection. While one of the AAW test scenarios was conducted, the weapon direction system which controls the SM-II surface-to-air missile began to operate improperly. In order to find the reason for this, the DE-RAT analyzed all of the recorded data extracted from the sensors and the weapons concerned with the functional chain of the SM-II AAW engagement, and detected a gyro anomaly which occurred at a system time of 47 *seconds*. Fig. 21 clearly shows that the gyro anomaly influenced the SM-II AAW engagement. The DERAT found that the reason was the improper update rate of the gyro heading data. After the optimization of the gyro heading update rate, the gyro data and weapon direction system were stabilized. As mentioned above, the DERAT was tested and confirmed to be an effective analysis tool for system integration.



Fig. 21 Gyro anomaly.

## CONCLUDING REMARKS

The intention of this paper is to suggest the DERAT as a data analysis tool for combat system integration and to prove the effectiveness of the DERAT by presenting the test results. The DERAT is believed to be helpful to develop a combat system which fulfills the end user's requirement and to timely deliver the combat system to the end user. Furthermore, the DERAT is expected to contribute to reduce the cost and time as well as the system engineering efforts significantly.

If an additional function is implemented, the DERAT will easily be used to support on-board team training, fleet exercise assessment, planned maintenance and repair of equipment regarding the equipment's failure history and trends, data base for future development, etc. Therefore, future study will be necessary to expand the availability of the DERAT as a life time support tool.

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