MULTISENSOR TACTICAL TARGET ACQUISITION ANALYSIS MODEL

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ABSTRACT

The role of tactical target acquisition and weapon delivery in any tactical mission is paramount to mission success. The Multisensor Tactical Target Acquisition Analysis Model (MTTAAM) was developed in-house (ASD/XRM) to support studies which involved the evaluation of tactical weapon systems. These studies required the evaluation of the integrated aircraft, sensors, and weapons performance. This paper addresses the model development, the integration of Tactical Target Acquisition with the LOWTRAN6 model (TACLOW6) into the flight path generator model, BLUEMAX-II model, with additional improvements to the model multisensor and weapon delivery capabilities. The sensor improvement includes modifications to expand the single sensor into an integrated multisensor (optical, electro-optical, and infrared) modeling. Furthermore, the methodology will address the interactions of aircraft dynamics, sensors, weapons, terrain, weather and target characteristics.

INTRODUCTION

The detection and destruction of enemy targets is primarily a function of the sensors capabilities to acquire the target and the agility of the aircraft to respond. Detecting a target and delivering a suitable weapon is continually more difficult due to the complexity of the target background, the low altitude flight profiles used, and the unpredictability of severe weather. The Multisensor Tactical Target Acquisition Analysis Model (MTTAAM) includes electro-optical sensors. The model currently has seven different sensors for target acquisition to detect and recognize the target. The model is flexible enough to add more, or new sensors easily. The seven sensor types contained in the model are:

Electro-Optical Sensors

1) Unaided visual
2) Forward-Looking Infrared
3) Active TV
4) Passive TV

The input data for the model includes detail flight profiles (BlueMax II), target descriptions, background, terrain, weather, and sensor parameters. The weather data can be calculated currently in the model by two methods. First, by using the LOWTRAN6 model and secondly, by using analytical calculations for the transmittance.

BLUEMAX-II

The incorporation of TACLOW6 into the BLUEMAX-II model and the additional modification for MULTI-SENSOR and ground target modeling will allow for simulation of the complete weapon system (aircraft, sensors, weapons, etc.) in a single model. During the operation of MTTAAM, the user will have the option of turning on a single or multiple sensors and compute (for given target/threat), the probability of detection and recognition of specific ground targets. This modification will add a sense of reality to the tactical target attack modeling capability of BLUEMAX-II and will allow for the evaluation of a complete weapon system operating against realistic ground threats.

BLUEMAX-II is an aircraft flight path generator developed by Fairchild Republic Co. as a part of the Tactical Aircraft Penetration Model contract with the USAF Studies and Analysis. It generates a description of the aircraft's status at short time intervals (.1 sec iteration time) that is suitable for input to one-on-one models such as MICHE-II (Surface-to-air Missile Model) or P001 (Anti-Aircraft-Artillery Model).

BLUEMAX-II is a pseudo five degree-of-freedom (5-DOF) model which simulates the flight of an aircraft over terrain (DMA 100m x 100m digital terrain) utilizing manual or automatic terrain following/terrain avoidance (TF/TA). As shown in figure 1, the model requires input data for the aircraft characteristics and performance (aerodynamic, propulsion, weights and stability), digital terrain data and mission profiles (way-points from batch command file or interactive commands from the user). The output of BLUEMAX-II is a flight path time history of aircraft position and orientation relative to the terrain as illustrated in figure 2. The output is used as input to the one-on-one analysis to determine the aircraft survivability for a specific mission (single sortie).
ASD/XRM obtained version 1.2 of BLUEMAX-II in 1985 and began making modifications to improve the modeling flexibility, capability and fidelity. These new modifications include improvements to the dynamic modeling, the addition of ground threats/targets, position of the threats/targets relative to the aircraft position and an option to switch between batch and interactive modes.

To illustrate how BLUEMAX-II has been used in recent studies, figure 3 shows a typical terminal area target attack profile for an air-to-ground missile (AGM) in a close-air-support (CAS) mission role. The aircraft ingresses at 200ft above ground level (AGL), climbs to altitude for target detection and acquisition, upon which the aircraft initiates a dive and track on target to the weapon release point and then returns to base or the loiter point flying at 200ft AGL.

A nominal aircraft was flown through this profile at a speed of 600 knots for both the minimum and maximum missile launch ranges. Figures 4 and 5 are the profile (figure 4) and planform (figure 5) views. These figures illustrate the comparison of the minimum and maximum missile launch ranges relative to the target location and terrain.

The profiles were generated utilizing the interactive mode which requires commanded input (throttle, pitch, role, load factor, etc.), from the user.

The relative position of the aircraft and target is continuously displayed to cue the user when to begin the pull-up to target attack. Currently, the detection and acquisition ranges are predetermined off-line prior to running BLUEMAX-II. The TACLONG model is used to compute the cumulative probability of detection and recognition for a specific aircraft sensor, (VISUAL, FLIR, TV-FLIR, etc.) and target type (MB, TANK, BUNKER). MTTAAM will be used to determine the capability of a complete weapon system to detect, recognize and attack tactical ground targets within the limitations of the aircraft, sensors, weapons and environment.

SENSOR

A set of user selected sensors are assumed to be turned on, and detecting a target as the flight begins. There are four types of sensors from which to choose. The input data for the sensor is explained here for the FLIR sensor. The other sensor data is explained in the reference (1) report. FLIR systems are represented in terms of Mean Resolvable Temperature (MRT). MRT is measured on the display, and is for a target of known spatial frequency, the temperature difference of the target above the background, which is resolvable to an observer at the 50 percent performance level. The input parameters used to indicate the coefficient of the MRT are ZK1 and ZK2. These coefficients are dependent upon the type of FLIR sensor. It is apparent from the definition of MRT that the SNR(DT) should equal the values determined by ROSELL for a given spatial frequency (XN) when apparent target temperature difference is equal to the MRT. The following equations are used from empirical curve fits to calculate the ZK1 and ZK2.
MRT = MRTO * EXP ( Beta * XN )

where: MRTO = ZK1 and Beta = ZK2

Figure 6 shows MRT versus CY/MR plot for fictional past, current and future FLIR systems. Included in TABLE A are all three past, current and future FLIR input data.

<table>
<thead>
<tr>
<th>FLIR 1</th>
<th>FLIR 2</th>
<th>FLIR 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRTO</td>
<td>0.15</td>
<td>0.04</td>
</tr>
<tr>
<td>BETA</td>
<td>0.112</td>
<td>0.4</td>
</tr>
</tbody>
</table>

TABLE A

Using the above data for all three FLIR systems, MTTAAM is run to generate cumulative probabilities of detection and recognition for all FLIR sensors. The figure 7 shows the result for these sensors. The result is a single sensor target acquisition in which three single sensors are operated independently. The multisensor run consists of running all three sensors simultaneously from beginning to end of the target acquisition period, and then recalculating the detection and recognition according to the maximum and minimum detection ranges that occur. Figure 8 shows multisensor cumulative probability of detection and recognition. Figure 9 compared single and multisensor probability of detection. Other multisensor output demonstrating several combinations of sensors types will be shown in the sensitivity section of this report.

MINIMUM-RESOLVABLE-TEMPERATURE (MRT)

MRT VERSUS SPATIAL FREQUENCY

CAPABILITY TO EVALUATE THE SENSORS

COMPARISON OF FLIR

Figure 7

MULTISENSOR DETECTION

THREE FLIR SENSOR

Figure 8

MULTI-SENSOR VS. SINGLE SENSOR ACQUISITION

THREE FLIR SENSORS

Figure 9

COMPARISON OF SINGLE AND MULTISENSOR

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The output of the model includes single glimpse and cumulative probability of detection and recognition of each sensor. Furthermore, the output is recalculated according to the type of sensors being used in order to maximize overall detection capability when selecting more than one sensor (i.e., the multisensor case). The output of the model consists of the various single glimpse probabilities, such as probability of the field-of-view, line-of-sight, search, and discrimination. Also, included in the output is the calculation of the atmospheric transmission and detection range. Furthermore, the cumulative probability detection and recognition is the most important output of all. The cumulative calculation for detection and recognition consists of three conditional probabilities (equation 1).

First, the probability that the target is in the view of the sensor is called the probability of clear line of sight \( P(CLOS) \), which is a function of the mask angle and field-of-view. Second, the probability that the target can be seen from the background clutter by the pilot is called the conditional probability of the search \( P(SEA) \). \( P(SEA) \) is a function of the glimpse time, background complexity, target area, and search area. Finally, probability that the pilot can distinguish the target is called probability of discrimination, which is a function of the signal-to-noise ratio.

\[
PAD = \sum_{{DIVE}} P(CLOS) \cdot P(SEA) \cdot P(DIS) \quad (Eq-1)
\]

All of these probabilities are calculated for each sensor and are used in the calculation of the multisensor probabilities. The multisensor calculation is as follows:

\[
P(A \cup B) = P(A) + P(B) - P(A) \cdot P(B)
\]

\[
MPAR = (PAR1 \cup PAR2) = PAR1 + PAR2 - PAR1 \cdot PAR2
\]

\[
MPAD = (PAD1 \cup PAD2) = PAD1 + PAD2 - PAD1 \cdot PAD2
\]

\[
MPAR = \text{MULTISENSOR PROBABILITY OF DETECTION}
\]

\[
PAD1 = \text{FIRST SENSOR PROBABILITY OF DETECTION}
\]

The above equations can easily be expanded to consider four individual sensors.

The post processor program is written to accommodate the graphic capability of both single and multisensor outputs. The program is written to calculate the multisensor cumulative probability of detection and recognition. The program compares both single and multisensor probability of detection and recognition in user defined output. The choice of the output is as follows:

5. Output of combination of #1 and #3.
6. All of the above.

**SENSITIVITY ANALYSIS**

In order to further demonstrate the capabilities of NTTAAM, several sample cases will be presented. During the validation phase of model development, eleven sensor combinations were examined. TABLE B lists the types of combinations which were considered. A standard set of baseline assumptions made for target specifications, environmental conditions, and flight profile assumptions are listed in TABLE C. The environmental conditions and terrain masking values correspond to the Fulda Gap region in Germany. Because our intent was to model non-specific systems, detailed system parameters are omitted from TABLE C.

**PARAMETERS**

Representative cases were selected from TABLE B and are presented below. We have assumed a baseline case which uses only unaided visual (human eye) and forward looking infrared (FLIR) sensors. Figure 10 shows the baseline plot generated from NTTAAM using the assumptions of TABLE C. The graph shows cumulative probability of detection (PAD) curves with respect to slant range for the independent visual sensor, independent FLIR, and resulting multisensor case. Note that the multisensor curve was generated according to the equations cited previously in this report. The multisensor plot illustrates the integration process in which each independent sensor detection curve is combined into an overall detection curve. As one might expect, the independent FLIR sensor provides greater detection ranges than that of the independent unaided visual sensor. Note that at large slant ranges, the combined visual/FLIR multisensor provides detection levels similar to that of the independent FLIR system. The multisensor case and independent FLIR curves are identical until the slant range is decreased to the point where the visual sensor can provide non-zero PAD levels to the multisensor calculation.

**SENSOR COMBINATIONS EVALUATED**

<table>
<thead>
<tr>
<th>Baseline</th>
<th>Visual</th>
<th>FLIR</th>
<th>Active TV</th>
<th>Passive TV</th>
</tr>
</thead>
<tbody>
<tr>
<td>CASE 1</td>
<td>+</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CASE 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CASE 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CASE 4</td>
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<td>CASE 5</td>
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<td>CASE 6</td>
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<tr>
<td>CASE 7</td>
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<tr>
<td>CASE 8</td>
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</tr>
<tr>
<td>CASE 9</td>
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<tr>
<td>CASE 10</td>
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</tr>
</tbody>
</table>

**TABLE B**

![Table B Image]

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BASELINE ASSUMPTIONS FOR SENSOR ANALYSIS

<table>
<thead>
<tr>
<th>Target</th>
<th>1 Tank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target Size</td>
<td>20 ft x 10 ft x 6 ft</td>
</tr>
<tr>
<td>Meteorological Visibility</td>
<td>6 NM</td>
</tr>
<tr>
<td>Relative Humidity</td>
<td>75%</td>
</tr>
<tr>
<td>Search Altitude</td>
<td>1000 ft</td>
</tr>
<tr>
<td>Mask Angle</td>
<td>2.1</td>
</tr>
</tbody>
</table>

SENSORS | SPEED (KNOTS) | OFFSET (FEET)
---|---|---
Visual | 450 | 0
FLIR | 450 | 0
ACTIVE TV | 450 | 0
PASSIVE TV | 400 | 0

Figure 11 summarizes the cumulative detection levels presented in Figure 10. At a slant range of 6250 feet, the visual sensor provides 32% PAD. At the same range, the FLIR and multisensor provide greater PAD levels of 66% and 77% respectively. Also indicated are the locations at which the FLIR and multisensor cases obtain 50% PAD and 51% PAD respectively.

Figure 12, indicates detection levels and ranges corresponding to CASE 8 cited in TABLE B. Detection levels are shown for three independent sensors and also for the combination multisensor. At the 6250 feet slant range, the visual sensor, once again, provides 32% PAD. At 6250 feet, the FLIR and passive television sensors achieve 66% and 58% PAD respectively. Note that the multisensor achieved 76% cumulative detection at the same range at which the "best" sensor (i.e., FLIR) provides only 66%. Also, note that at a slant range of 1200 feet, the multisensor has reached 77% which the maximum value achieved any of the independent sensors is only 54%. Clearly, the integration of several sensors can improve overall target acquisition and mission effectiveness.

MULTI-SENSOR VS. SINGLE SENSOR ACQUISITION

Figure 13, summarizes CASE 10 from TABLE B. In this particular example, all four available sensors are operated. Detection levels for each independent sensor and multisensor cases are indicated. At a slant range of 7760 feet, the FLIR achieves 66% PAD while the other three independent sensors reach much lower PAD values. However, at the same range, the multisensor achieves 89%. It is interesting to note that at large slant ranges, the integration of each independent sensor's detection information can increase the overall cumulative probability of detection to an impressive 77% PAD, (at 13,000 feet) while the "best" detection level of any independent sensor reaches only 50% PAD.
In the process of presenting the above representative cases, we have demonstrated only one facet of MTTAAM. The cases shown concentrated only on cumulative probability of detection (PAD) for singular sensor and multisensor applications. In addition to the presented material, MTTAAM can also calculate glimpse probability of detection (P3D), glimpse probability of recognition (P3R), and cumulative probability of recognition (PAR). Additional information can be found in reference (1) regarding these calculations.

**CONCLUSION**

The multisensor Tactical Target Acquisition Analysis Model (MTTAAM) can be used in the evaluation of different sensors for both current and future systems. Also, it can aid in developing new technology sensors. The model was developed for use in future tactical air-to-ground in-house studies. The model is flexible enough to modify for use in various studies which involve air-to-ground and ground-to-air analyses. Currently, the program has the capability of using only Electro-Optics sensors. In the near future, a radar portion will be added to have the capability for both EO and RF sensors. MTTAAM is written in FORTRAN, and is currently used on a MicroVax computer. It contains approximately 3000 lines of computer code without the LOWTRAN6 and BLUEMAX-II code. The model is very sensitive to weather, flight profile and environment. Furthermore, the model is a dynamic target acquisition model rather than a static model.

**REFERENCES**

1. KIM, TONY; RICKELS, WILLIAM; McARTHUR, JOHN; "TACTICAL TARGET ACQUISITION WITH LOWTRAN MODEL," VOLUME I & II, ASD/XRM, WPAFB OH, 1988.
