VERIFICATION OF THE TARGET ACQUISITION WEATHER SOFTWARE (TAWS)

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ABSTRACT

The Air Force, Navy, and Army are in the process of upgrading the Electro-Optical Tactical Decision Aid (EOTDA). The EOTDA was used to predict target acquisition under degraded weather conditions. The upgraded program is called the Target Acquisition Weather Software (TAWS). New features of TAWS will include automated data access, upgraded path radiance routines, and inclusion of NVESD's sensor performance model, Acquire. TAWS is also being linked to the Army's rule-based Integrated Weather Effects Decision Aid (IWEDA) in order to provide more detailed effects and quantitative information. To quantify the effects of upgrading the SPM on target acquisition range, a comparison of TAWS version 1 with Acquire has been undertaken.

1. Introduction

The range at which a target can be detected on the battlefield is a valuable piece of information for the battlefield commander. Detection and recognition ranges depend upon the target and background characteristics, atmospheric propagation, and sensor performance. Weather tactical decision aids (TDAs), which provide information on sensor performance under adverse weather conditions, come in two forms: rule-based and physics-based. Rule-based TDAs, such as the Army's Integrated Weather Effects Decision Aid (IWEDA)[1], are constructed using rules that have been collected from field manuals, training centers and schools, and subject matter experts. An example of one such rule would be "usage of TOW2 is not recommended for visibilities less than 3km". Physics-based TDAs, such as TAWS[2] and Acquire[3], employ physics calculations that have their basis in theory or field measurements. Thus, a physics-based TDA employs routines and physics that allow it to ascertain the probability of detecting a given target at a given range under existing or predicted weather conditions. This is in contradistinction to the rule-based TDA, which would *suggest* that a particular system be used under given weather conditions; no target is required. The trade off between target acquisition (physics-based) and system selection (rule-based) is run time: rule-based TDAs run considerably quicker than physics-based TDAs.

2.0 TAWS-Army

2.1 TAWS

The Air Force's Electro-Optical Tactical Decision Aid[4] (EOTDA) was developed to provide the user with a single piece of software to evaluate the combined effects of target to background contrast, atmospheric transmission, and sensor performance on the range at which a target can be detected by an imaging device. The model treats detection by direct view optics devices, such as the human eye and binoculars; image intensifiers such as night vision goggles; and thermal imaging devices. TAWS, a Tri-Service program, is an upgrade of the EOTDA. Improvements and additions found in TAWS include Army targets and sensors, the Night Vision and Electronic Sensor Directorate's range performance model for target acquisition systems, Acquire, a new atmospheric scattering routine for examination of all possible geometrical scenarios (e.g. air-to-ground, ground-to-air, ground-to-ground, and air-to-air) and a complete new graphical interface that allows for user supplied or automatic weather ingest. Additional information concerning TAWS can be found elsewhere in these proceedings[2].

2.2 IWEDA

IWEDA, an Army Research Laboratory developed rule-based TDA, simplifies the manner in which environmental impacts on weapon systems are displayed to the user. IWEDA provides current and forecast qualitative impacts on approximately 100 military operations (e.g., NBC Chemical, Airborne, Cross Country Maneuvers, etc.) and weapon systems (e.g., attack helicopters, fixed wing aircraft, personnel, etc.) to both meteorologists and non-meteorologists throughout the Army Battlefield Command System. IWEDA "rules" are compared against the forecast Gridded Meteorological Data Base (GMDB), which is resident on the Army's Integrated Meteorological System's (IMETS). Users configure systems as to how they will be employed, select the systems or missions they wish to see impacts on, then click a button to have the impacts automatically computed via internal queries to the database tables. Once the queries are completed, a color-coded (red, amber, green) matrix is displayed conveying the impact of the environment on the systems of interest (figure 1). Drill down capabilities are available via mouse clicks such that the user can query and view various levels of information (e.g., condensed or detailed text impact statements, spatial distribution of the impacts via a map overlay [figure 2], etc.) depending on their requirements. For example, by clicking the left mouse button anywhere over the map overlay, the full impact statement on the particular item of interest is retrieved and displayed to the user. Thus, it was a simple extension of this concept to include TAWS and allow the computation and display of quantitative target detection and recognition ranges from within the familiar IWEDA GUI. Coupling with the Army's GMDB also allows target acquisition to be accomplished in near real-time under forecast weather conditions on a tactical scale.

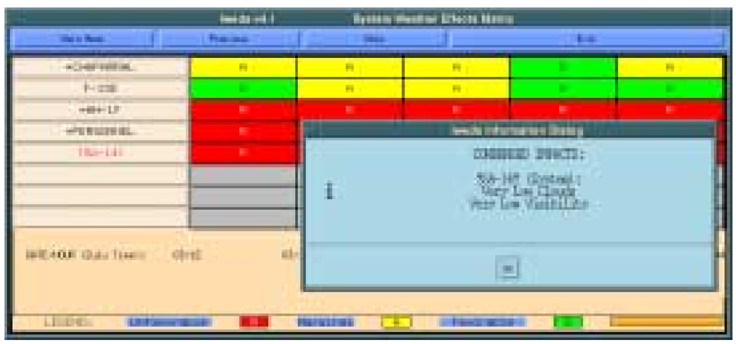

Figure 2. IWEDA Weather Effects Matrix (WEM) with Condensed Impacts

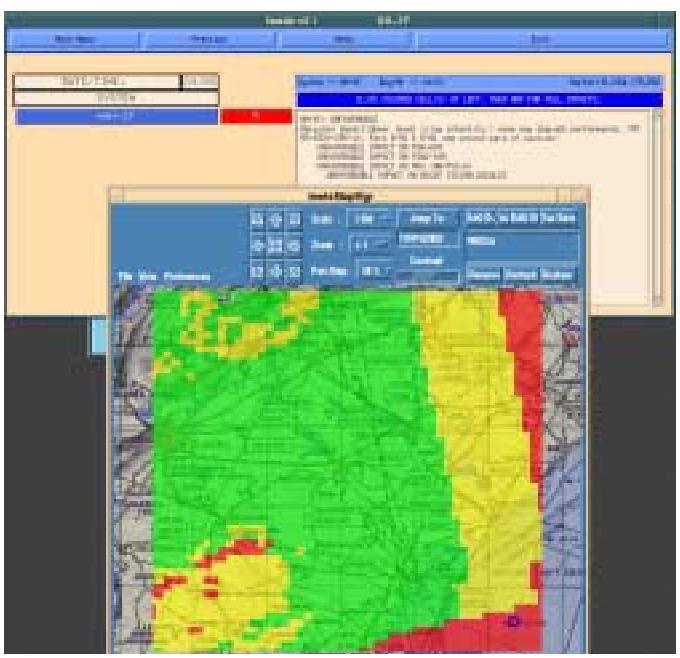

Figure 1. IWEDA Map Overlay for AH-1F (Cobra) Helicopter with Full Impact Statement

2.3 Integration of TAWS with IWEDA

In accordance with the Army's IMETS philosophy of keeping input as simple as possible a variant of TAWS is being used in IMETS. This variant is called TAWS-Army (TAWS-A) and is functionally equivalent to TAWS. The salient differences are in allowed user input: TAWS has numerous GUIs to allow automated or manual input and manipulation of meteorological parameters. Since TAWS-A has automatic ingest of weather conditions through the Army's GMDB there will only be one GUI (figure 3) which is used to initially select sensor, target and background information. Currently some additional information is required about the background aerosol. Since the purpose of TAWS-A is to aid the commander make rapid decisions concerning sensor and/or platform selection, the graphical output from TAWS-A is also be different from TAWS. For sensor selection TAWS-A output is in the form of bar charts (figure 4); weapon fans (figure 5) will be available in a future version when the digital terrain elevation has been incorporated into IWEDA.

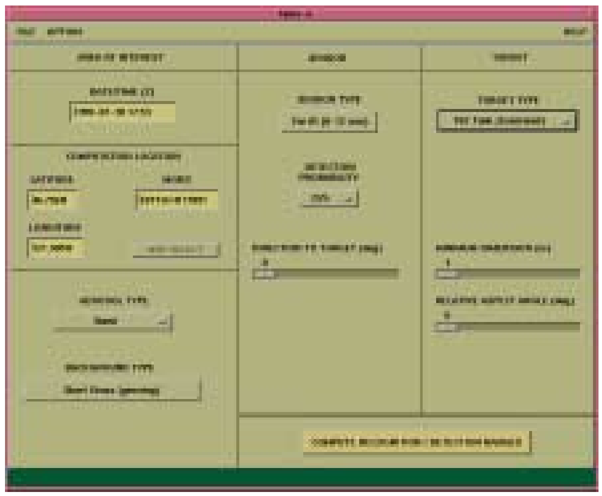

Figure 3. TAWS-A Input GUI

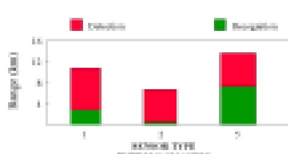

Figure 4. TAWS-A Example Sensor Selection

Figure 5. TAWS-A Example Weapons Fan

Detection and recognition ranges are displayed via bar charts (e.g. figure 4) and the weapons fan will be overlaid on top of the map display (e.g. figure 5). This feature will color code the detection and recognition ranges for numerous azimuths either over a full circle or some smaller arc as specified by the user. Digital terrain elevation data will also be read such that masking due to intervening terrain can be incorporated into the weapon fan display. Eventual incorporation of threat sensors will allow comparison of friendly and threat systems for aiding in the determination of when and where one force may have the advantage over another.

3. Comparison of TAWS with Acquire

3.1 Background

As mentioned above, the latest version of Acquire is slated to replace the current sensor performance model (SPM) resident in TAWS. This replacement raises the question of what differences may arise due to different methodologies between the SPM in TAWS and Acquire. To answer this question a comparison of target acquisition ranges produced by TAWS and Acquire was undertaken. It should be noted that this comparison in no way should be construed as a validation of the target acquisition ranges *per se*. Rather we are examining what, if any, differences arise due to the underlying SPMs.

3.2 Acquire SPM

The Acquire model is the Army's standard algorithm for modeling man-in-the-loop search and target acquisition process in combat simulations. It predicts the probability of acquiring the target at various classification levels in the visible, near infrared and infrared wavelengths. The Acquire model includes range prediction methodologies for both target discrimination (minimum resolvable temperature - MRT) and target spot detection (minimum detectable temperature - MDT). For a target imbedded in a non-uniform or cluttered background, discrimination of characteristics that separate the target from the background is required in order to perform detection. Similarly, discrimination of target characteristics and features is required in order to perform recognition and identification tasks among classes and types of targets. Target discrimination range predictions are made using a two-dimensional formulation of the Johnson cycle criteria methodology[5]. Johnson reported the 50% point (referred to as N_{50}) on a curve defining what portion of an ensemble of observers was able to perform a particular discrimination task. Various levels of clutter may be handled by varying N_{50}. All input is entered manually, that is, there is no GUI or automated input of parameters; input parameters include sensor, target and background temperature difference, and intervening atmospheric data. Acquire will predict either static or time-dependant target detection. For comparisons in this paper, we are only concerned with static target detection at infrared wavelengths determined via MRT or MDT criteria.

An updated version of Acquire, discussed in detail in ref. 6, was issued in June 1990. The model update consisted of two parts: "FLIR90," which predicts laboratory measures, and "Acquire," which predicts field performance. In FLIR90, predicted or measured horizontal and vertical MRTs are averaged at a particular temperature. This effective MRT is used along with modified values of N_{50} for the different discrimination tasks to predict range performance. The N_{50} for a particular task using the more recent 2-D version of the model is found by multiplying the original 1-D N_{50} values by 0.75. The amount of shift was determined by requiring the range predictions for the 2-D model to predict correctly the results of the field tests, which served as validation for the original (1-D) model.

Thus, the appropriate N_{50} to use, at the detection level, would be 1.0 for TAWS, which corresponds to .75 for Acquire.

3.3 TAWS SPM

TAWS' SPM is derived from work done in the 80's at the Air Force Avionics Laboratory (now part of AFRL); the main differences between TAWS and the Avionics research grade code lies primarily in the underlying thermal model (TCM2), with TAWS using a scaled down version of that model. The SPM resident in TAWS is based on the Johnson methodology hardwired to the 50% probability level. TAWS predicts lock-on range based on signal-to-noise ratio thresholds, hot spot detection based on MDT methodology, and discrimination detection range based on MRT methodology. Thus, all other parameters being equal, TAWS detection ranges should be approximately equal to those predicted by Acquire at the 50% probability of detection level. Clutter is automatically computed based on an empirical algorithm[7] and is a factor in determination of the number of cycles on target.

3.4 MDT vs MRT

MDT is only appropriate for targets against a uniform or unstructured background, such as aircraft against a clear or overcast sky. Searching for tanks against a terrain background requires the MRT approach. Additionally, the MDT approach only represents detection whereas the MRT approach is required for target recognition and identification. If a target is hot enough, the MDT approach predicts target detection even though the target may be smaller in size than a FLIR detector element. For all practical purposes, the MDT approach is not used in the Army's combat simulations since recognition or identification is required before firing on a target. It should also be noted that in a cluttered environment the target would not be the only hot spot.

4. Comparisons

4.1 Scenarios

To compare these two complex target acquisition models requires standardization of as many parameters as possible. To accomplish this one weather scenario was used in conjunction with one sensor and target, both with fixed orientations.

A winter scenario was chosen and examined using an exercised T-80 against two backgrounds (vegetation and snow) at infrared wavelengths. The sensor and tank were aligned such that the sensor always had a frontal view of the tank; the sensor height was fixed at 300 ft. To minimize shadow effects the date was fixed at 21 December at a local time of 12N. The location was also fixed at latitude of 37° 32' N, longitude of 127° 00' E (Seoul, S. Korea). The weather conditions include (see table 1) clear skies with varying visibilities and relative humidities, and overcast skies with varying visibilities and relative humidities. Additional cases were run including light/heavy fog conditions, snow, drizzle, and thunderstorms.

Table 1. Weather Conditions used in the Study

RH **Precip**		30% none	50% none	80% none	100% light fog	100% heavy fog	80% snow	90% light rain	90% moderat erain
Cloud Cover		clear	clear	clear	clear	clear	~~clear~~	~~clear~~	~~clear~~
		overcast	overcast	overcast	overcast	overcast	overcast	overcast	overcast
Visibility	2 km		2	2	2	2	2	2	2
	5 km		5	5	5	~~5~~	5	5	~~5~~
	10 km		10	10	10	~~10~~	10	10	~~10~~
	15 km		15	15	15	~~15~~	15	15	~~15~~

4.2 Model Runs

TAWS was run using winter climatology along with the weather conditions listed in table 1 with the infrared sensor viewing an exercised T-80 tank from a frontal view. The clutter level was initially set at "low." Output values from TAWS were fed directly into Acquire thereby insuring that the inherent delta-T and atmospheric transmission values were identical in both programs. Sensor MRT curves were examined and, after appropriate conversion from 1-D to 2-D, were found identical. The initial runs did not agree well: TAWS results agreed with Acquire's at the 5% probability level (recall TAWS' results are for the 50% level). To reconcile this disparity, various input parameters were examined. The first parameter examined was the clutter level. Spot checks of runs with TAWS clutter level changed from "low" to "high" resulted in minimal decreases in detection ranges. While this helped, the improvement was marginal – probability level agreement was raised to the 10% Acquire level. Other possible areas of input parameter disagreement were examined. Since target size is critical to obtaining meaningful results, this was the next area examined. Acquire's built in tabular lookup tables use the square root of the target projected area; TAWS uses the projected dimensions determined from initial values in its target data base coupled with geometrical considerations (sensor view angle, sensor depression angle). Sensor view angles in both programs were held constant at a frontal view. Projection effects over the detection ranges (~15 to 30 km) and sensor altitude (~100 m.) used proved to be negligible. TAWS and Acquire target dimension databases were examined next; the results were rather surprising and are presented in table 2. Also presented in table 2 are T-80 dimensions determined through a web search.

Table 2. T-80 Dimensions

Source	Length (m)	Width (m)	Height (m)
Acquire*		3.59	2.64
TAWS	9.1	4.64	3.73
CASTFOREM	6.75	3.55	1.5[%]
WWW1	9.7	3.6	2.2
WWW2	9.9/7.4[#]	3.4	2.2
WWW3	7.01	3.6	2.20

* values are square root of projected area
[#] gun forward/hull
[%] does not include turret

It is apparent that the values in TAWS do not agree with those found elsewhere. The values selected for the various dimension sizes probably represent different configurations of the T-80 (c.f. figures 6 and 7). Further, using the gun forward length is not representative of the actual target size and produces overly optimistic detection

Figure 6. T-80B

Figure 7. T-80U

ranges. Nevertheless, since we were examining algorithm agreement and not target data bases, a frontal projected dimension of 4.19 m was subsequently used in the Acquire runs. This raised the agreement level considerably to ~30% probability level. These results are presented in figure 8.

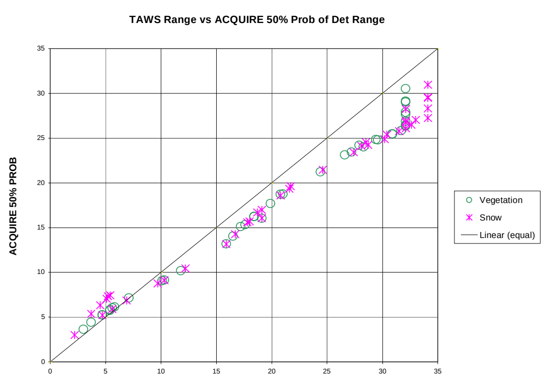

Figure 8. Acquire vs. TAWS detection ranges at 50% probability of detection

Examination of figure 8 shows a definite "binning" effect for the TAWS calculations around 32.1 km for vegetation and 34.1 km for snow backgrounds respectively. Due to sensor optical resolution limits, there exists a maximum value for MRT detection range. Since this limit scales with target height a determination can be made using values taken from ref. 4 table A.1-2. For the sensor and target chosen the range limit turns out to be 32.8 km, in good agreement with the TAWS values.

TAWS computes target detection ranges using two different discrimination algorithms: MDT and MRT. The range chosen for display is the longer of the MRT or MDT ranges. Results from each algorithm were individually compared with the Acquire

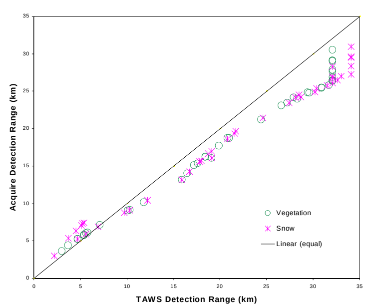

Figure 9. Acquire vs. TAWS detection ranges at 50% probability of detection using MRT algorithm

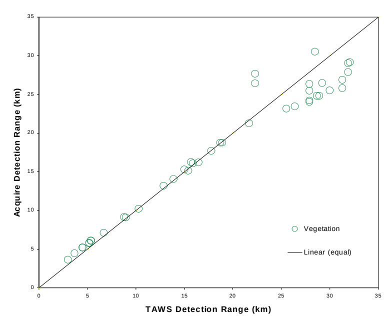

Figure 10. Acquire vs. TAWS detection ranges at 50% probability of detection using MDT algorithm

runs and are presented in figures 9 (MRT) and 10 (MDT). Examination of those figures shows that the MDT comparison agrees well with Acquire. Close examination of these ranges, presented in table 3, shows that figures 8 and figure 9 are nearly identical, that is, for the scenario chosen MRT ranges are usually larger than MDT ranges. This result is puzzling, since conventional wisdom holds that MDT ranges are typically longer than MRT ranges.

Targets frequently have "hot spots" delineated by engine location, comfort heaters, exercised tracks, etc., which affects the range at which the target is discerned. Since hot spot detection (MDT) describes the situation in which the target is detected as an unresolved spot against the background and MRT detection describes perceiving the target as a definite shape, ranges using MDT detection are usually longer than those determined using MRT detection. To examine the possibility of a hot spot on MRT/MDT detection, the orientation of the T-80 was varied such that the sensor viewed the tank from the front, rear, and both sides. Results are presented in table 3. For the most part, MRT ranges are still longer than MDT ranges. Thus, future studies will have to examine the target model and the MRT and MDT algorithms in more detail to shed light on this apparent enigma.

Table 3. MRT / MDT range (km) as a function of T-80 tank heading and state, and winter weather conditions for sensor 1011

Tank Heading	0		90		**180**		270	
	MRT	MDT	MRT	MDT	MRT	MDT	MRT	MDT
30% RH (1.51 AH); clear; visibility 2 km	.818/km transmission							
Exercised	25	23	24	19	21	19	24	20
Idle	27	25	23	19	21	19	23	19
Off	19	17	22	19	19	18	23	20
50% RH (2.45 AH); clear; visibility 5 km	.892/km transmission							
Exercised	32	33	32	33	29	29	32	34
Idle	32	34	32	31	29	29	32	32
Off	27	21	32	31	27	28	32	31
80% RH (3.89 AH); clear; visibility 5 km	.874/km transmission							
Exercised	32	30	31	28	27	26	32	29
Idle	32	31	29	28	27	26	30	27
Off	24	19	28	27	24	24	29	27
80% RH; overcast; visibility 2 km	.791/km transmission							
Exercised	23	20	19	15	17	14	19	16
Idle	24	21	16	13	17	14	16	13
Off	14	12	14	9	11	11	14	11

AH is in g/m^3

4. Conclusions

The results that we have presented here are limited. Other areas, such as the effects of clutter, need to be more closely examined. In addition, the closer agreement with MDT values rather than MRT values needs to be scrutinized. The agreement of TAWS MDT detection ranges with those determined by Acquire is satisfying. Overall the results agree reasonably well; TAWS detection ranges are somewhat optimistic compared to Acquire's ranges.

This study is ongoing; final results will appear in an Army Research Laboratory technical report.

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