TAWS AND NOWS: SOFTWARE PRODUCTS FOR OPERATIONAL WEATHER SUPPORT

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The Target Acquisition Weather Software (TAWS) and Night Vision Goggle (NVG) Operations Weather Software (NOWS) are being developed for use by tactical weather teams supporting Air Force, Army, Navy, and Marine operations. Supported missions include surface attack, close air support, air interdiction, search and rescue, helicopter refueling, and target identification. Mission planners, pilots, and other tactical forces need to know if it is possible to conduct their missions under expected weather conditions using electro-optical weapon and target acquisition systems. TAWS and NOWS incorporate a modular system design that allows “plug and play” upgrades, a user-friendly graphical user interface (GUI), state-of-the-art physical models, and automated access to meteorological and geographic databases. TAWS and NOWS run on a PC with Windows 95/98/NT. The GUI requires information in three distinct modules, to facilitate information flow from different areas of expertise: target information from the intelligence targeteer; mission parameters from the pilot; and the weather prediction from the forecaster. The physical models include infrared (IR), television/NVG, and laser. TAWS and NOWS access weather forecasts through the Air Force Weather Information Network (AFWIN) and geographic information through several terrain and mapping databases; manual data entry is supported in the event communications paths to automated sources are not available. TAWS and NOWS predict detection or lock-on range for a series of targets. For each target, calculations may be performed for a series of potential times, approach azimuths, weapons systems, and sensor elevations. TAWS and NOWS provide users with output products that can be tailored to their needs. Predicted lock-on and detection ranges can be used to assist in route selection, attack planning, and sensor prioritization.

Objective

Tactical weather teams supporting Air Force, Army, Navy, and Marine operations need to assist mission planners, pilots, and other tactical forces in determining if it is possible to conduct their missions under expected weather conditions using electro-optical weapon and target acquisition systems. The Target Acquisition Weather Software (TAWS) and Night Vision Goggle (NVG) Operations Weather Software (NOWS) are being developed to help weather teams provide this support. Supported missions include surface attack, close air support, air interdiction, search and rescue, helicopter refueling, and target identification.

TAWS is designed to update and improve upon the Electro-Optical Tactical Decision Aid (EOTDA), which has been used operationally for many years. TAWS encompasses recent modeling and hardware/software technology improvements, bringing state-of-the-art solutions to a modern Windows environment. NOWS is designed to provide similar support for nighttime missions where pilots are relying on NVGs. NOWS brings the additional capability to support air-to-air operations.

TAWS and NOWS include automated access to weather and geographic information, as well as target and sensor databases, to provide maximum usability. They can handle multiple targets, locations, sensors, and sensor altitudes in a single analysis. They implement a modular system design that leaves room for “plug and play” upgrades. They feature a user-friendly graphical user interface (GUI) that runs under Microsoft Windows 95/98/NT and takes advantage of many standard Windows features. The GUI interfaces to several physical models, including 3-5 μm and 8-12 μm infrared (IR), television/NVG, and 1.06 μm Laser. Other models may be included later as user requirements continue to evolve. TAWS and NOWS include both tabular and graphic output products that can be tailored to users' needs.

This paper provides a summary of the TAWS and NOWS software, as well as a description of progress made during the past year.

TAWS and NOWS System Design

TAWS and NOWS include a modular, expandable system design. A diagram depicting the overall system design concept is shown in Figure 1. The concept shows the core code, or GUI, controlling a series of physical models and a series of modular processes. This process flow concept is detailed in Figure 2. The core code accesses external databases when necessary and creates/accesses internal databases when necessary. This data flow concept is detailed in Figure 3. The intent is to add new processes or data sources to the overall system architecture as they become available for each version.

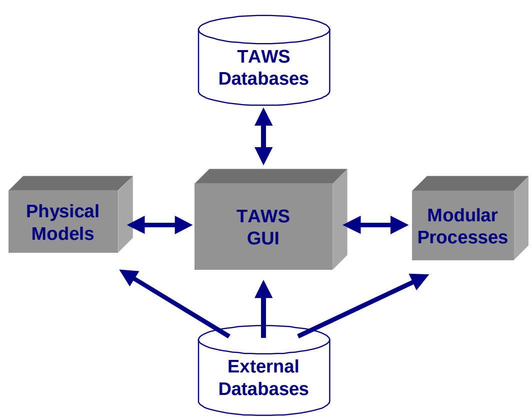

Figure 1. System Design Concept

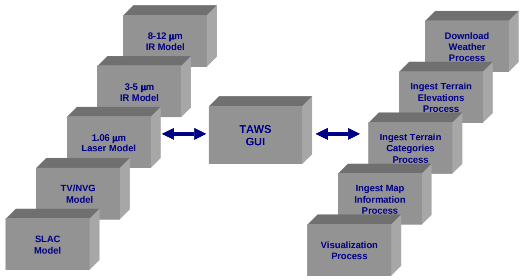

Figure 2. Process Flow Concept

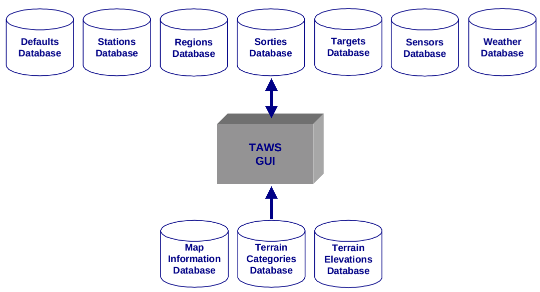

Figure 3. Data Flow Concept

Graphical User Interface (GUI)

The TAWS/NOWS GUI is designed to be goal-oriented. Three goals, or analysis types, are implemented, as well as a system defaults module. A representation of the high-level GUI design is shown in Figure 4.

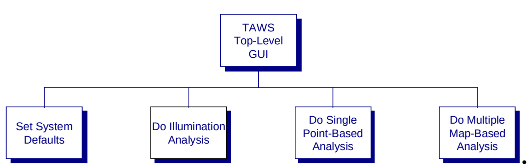

Figure 4. GUI Concept

The GUI processes input from several types of data sources, passes parameters to the appropriate physical models, invokes the models, and generates goal-dependent output products. The GUI for each of the three analysis types is described in a section below.

The TAWS/NOWS GUI runs under Windows 95/98/NT and is planned to be easily upgradable to later releases of the PC-Windows environment. The GUI uses tab dialogs, spinners, radio buttons, sliders, and other standard tools wherever possible to minimize the amount of work the user has to do.

Illumination Analysis

Illumination analysis involves the computation of solar and lunar ephemeris information for a specified location and a series of days. A mission planner, for example, might be interested in an illumination analysis to determine the time of sunset for a particular mission date and location.

The GUI for the illumination analysis, shown in Figure 5, consists of a single window, or wizard, that guides the user in entering the input parameters and producing the output products.

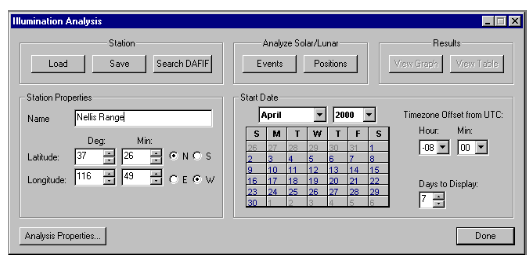

Figure 5. Illumination Analysis GUI

Single, Point-Based Analysis

Single, point-based target acquisition analysis involves detailed sensor performance predictions for targets at a single geographic location. A mission planner, for example, might be interested in a point-based analysis to predict detection range for a particularly important target as a function of time.

The GUI for the single, point-based target acquisition analysis, shown in Figure 6, consists of a single window, or wizard, that guides the user in entering the input parameters and producing the output products.

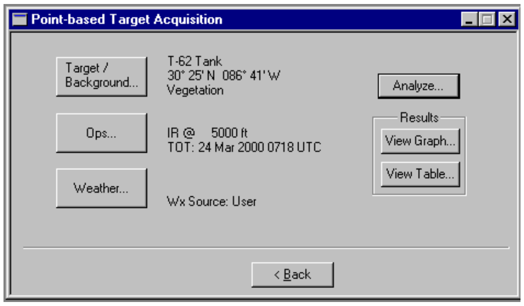

Figure 6. Point-Based Target Acquisition Analysis GUI

The GUI requires information in three distinct modules, to facilitate information flow from different areas of expertise: target information from the intelligence targeteer; mission parameters from the pilot; and the weather prediction from the forecaster. Status information for these three components is shown in the wizard. Once the three types of information have been entered, an analysis may be run. The point-based target acquisition analysis allows the user to analyze multiple targets at the location, multiple sensor platforms on the delivery aircraft, and multiple aircraft elevations at once.

Multiple, Map-Based Analysis

Multiple, map-based target acquisition analysis involves detailed sensor performance predictions for a series of target locations along a mission route. A mission planner, for example, might be interested in a map-based analysis to predict detection range for a series of key targets as a function of time.

The GUI for the multiple, map-based target acquisition analysis consists of a series of progress charts that lead the user through the various steps of defining a region on the map, adding targets to the region, selecting a subset of targets and a date/time for a mission, gathering and verifying the weather forecast, running the physical models, and generating output products. The GUI for the region definition step is shown in Figure 7.

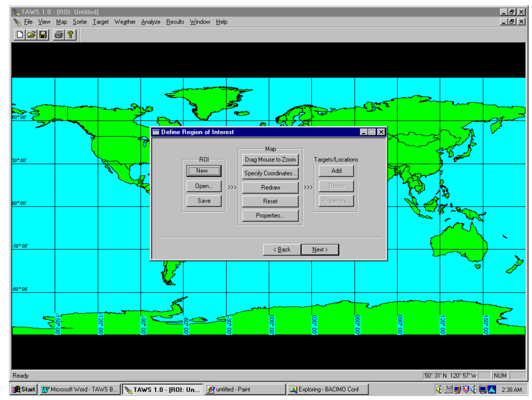

Figure 7. Map-Based Target Acquisition Analysis GUI

The GUI for the map-based target acquisition analysis is based on the concept of geographic regions of interest. Using a point and click interface, the user is able to pick out a geographic region of interest from a world map. The selected region is drawn as a detailed map and serves as the background for many of the operations of the GUI.

Once the user has selected a region of interest, the GUI allows the user to place multiple targets in the region. Once a target has been placed on the map, the user enters target-specific information into an input form. The information is saved to a database. TAWS and NOWS allow users to simultaneously manage a set of target locations within a region of interest. The user is able to switch quickly from location to location without losing any information.

The GUI allows the user to choose, using a point and click interface, a subset of the region's targets to analyze. The user is able to pick a single target to analyze, or a group of targets that are organized into a mission. Once a target has been selected, the user enters tactical information, such as the planned time-over-target, the sensor or sensors used to detect the target, and the sensor elevation into an input form. The GUI depicts the mission graphically by showing route lines between the target icons, representing the flight path. The GUI supports multiple missions, so users are able to quickly analyze alternatives and compare results.

The final step in the input sequence is to download and edit the weather forecast. TAWS and NOWS include an automated download capability for the Air Force Weather Information Network's (AFWIN's) MM5 meteorological forecast data. TAWS will also include an automated download capability for the Navy Tactical Environmental Data Server's (TEDS') NOGAPS and COAMPS forecast data. While the weather download is automated, the user is always given the chance to override the forecast before the TAWS/NOWS physical models are run.

Once the region has been defined, the targets added to the region, the tactics input, and the weather data ingested, the underlying physical models can be executed. The GUI manages all communication with the physical models. After running a model, the user is able to generate and examine the output products.

Target Database

TAWS and NOWS include a selection of predefined targets. Targets fall into two categories: vehicular (tanks, aircraft, trucks, etc.) and stationary (bridges, buildings, SAM sites, etc.). All target information is located in external data files, allowing updates to the target database without modifications to the software. It will be possible, through the use of a centralized World Wide Web site, for new targets to be shared with multiple users, thus building a more extensive target database.

A future version of TAWS will include a customized targets option, where the user will be able to add his own targets to TAWS by entering parameters into an input form. Once saved to the target database, the target will be available for use at any time.

Sensor Database

TAWS and NOWS include a selection of predefined sensors, as well as a facility for the user to create customized sensors. Current TAWS sensor types include 3-5 μm IR, 8-12 μm IR, TV, NVG, and 1.06 μm Laser designators/receivers/rangers, while NOWS supports only the NVGs. The list of TAWS sensor types can grow over time as additional physical models are added. All sensor information is located in external data files, allowing updates to the sensor database without modifications to the software. It will be possible, through the use of a centralized World Wide Web site, for new sensors to be shared with multiple users, thus building a more extensive sensor database.

TAWS and NOWS currently include a customized sensors option. The user is able to add his own sensors by entering parameters into an input form. Once saved to the sensor database, the sensor is available for use at any time.

Meteorological/Environmental Data

To enhance usability, the TAWS/NOWS GUI makes use of several strategies to reduce the weather data entry burden on the user.

- TAWS and NOWS include an automated download capability for AFWIN's MM5 meteorological forecast data. TAWS will also include an automated download capability for the TEDS NOGAPS and COAMPS forecast data. While the weather download is automated, the user is always given the chance to override the forecast before the TAWS/NOWS physical models are run.
- An attempt is made to derive parameters that are not directly available from automated sources. Aerosol type, for instance, is derived from visibility and terrain category.
- User-friendly input forms allow the user to manually input weather information. These data entry forms make maximum use of graphical, easy-to-understand interfaces as well as allow textual input.
- Since the GUI allows and encourages working on several targets at once, it is possible to copy weather information from one target to the next.

All parameters in the weather GUI are tagged with a color-coded source: AFWA, Derived from AFWA, TEDS, Derived from TEDS, Copy, User, and Defaults. The tags are shown to assist users, who may have little time to massage the input parameters, in prioritizing their work.

Geographic Data

The geographic information required by TAWS and NOWS includes mapping information and terrain categories. TAWS and NOWS use the National Imagery and Mapping Agency’s (NIMA's) Vector Smart Map Level 0 (VMap0) as the primary source of geographic information. VMap0 provides multiple map features such as political boundaries, elevation contours, hydrography, industry, physiography, population, transportation, utilities, and vegetation.

TAWS/NOWS use the DeFries and Townshend Land Cover Classification Map (1994a), a global land cover database, to obtain default information about target background and general target area albedo. This database is a product of the remote sensing community, derived from Advanced Very High Resolution Radiometer (AVHRR) Normalized Difference Vegetation Index (NDVI) satellite data. This land cover database has only coarse resolution, 1 degree by 1 degree, but it can be used to supply defaults for the user to override if necessary. TAWS/NOWS will update its global terrain database as higher-resolution databases become available.

Physical Models

TAWS/NOWS contain several component physical models. NOWS and TAWS include a solar/lunar ephemeris model and an NVG/TV model; TAWS also includes an MWIR (3-5 μm) / LWIR (8-12 μm) IR model and the 1.06 μm Laser model. These component models are briefly described below.

Ephemeris Model

The TAWS/NOWS illumination model computes solar and lunar positions and event times using the U.S. Naval Observatory's Solar-Lunar Almanac Code (SLAC). The SLAC (Bangert, 1998a; Bangert, 1998b) computes the horizon coordinates (altitude and azimuth) of the sun and the moon for a specified location and time. The SLAC also computes the fraction of the moon illuminated. TAWS/NOWS also use the SLAC to compute the times of sunrise, sunset, moonrise, moonset, and the times of nautical twilight.

Mid- and Long-Wave Infrared Model

The 3-5 μm and 8-12 μm IR model contains several components: a target contrast model, an atmospheric transmittance model, and a sensor performance model. The Thermal Contrast Model #2 (TCM2) (Johnson, 1991) is used to compute target and background temperatures and thermal contrast for some of the older TAWS targets, while the state-of-the-art Multi-Service Electro-optic Signature (MuSES) (Johnson et al., 1998) model is used for the newer TAWS targets. The transmittance model estimates the atmospheric attenuation between the target and the sensor using extinction coefficients derived from LOWTRAN 7 (Kneizys, 1983). The sensor performance model uses the apparent contrast and the target size to estimate the maximum detection or lock-on range for the target.

TV/NVG Model

The TV/NVG model contains several components: an atmospheric transmission model, a target contrast model, and a sensor performance model. The Fast Atmospheric SCATtering (FASCAT) model (Hering, 1981 and 1983; Hering and Johnson, 1984) is used to compute atmospheric optical properties, direct and diffuse components of radiance in the target scene, and path radiance and transmission between the target and the sensor. The target contrast model computes the zero-range inherent target and background radiance and the apparent contrast at the sensor's range. The sensor performance model uses the apparent contrast and the target size to estimate the maximum detection or lock-on range for the target.

Laser Model

The 1.06 μm Laser model contains several components: a target/background model, a transmittance model, and a sensor performance model. The simplified Laser target/background model uses only the reflectivity of the target and background at 1.06 μm. LOWTRAN-based extinction coefficients for aerosols and rain (Kneizys, 1983) are used to predict the degradation of laser energy as it propagates through the atmosphere. The sensor performance model computes the minimum detectable signal required at the receiver for successful ranging or lock-on, and iterates to determine ranging or lock on range. The range is a function of the laser pulse energy, the atmospheric transmission between the designator and the target or background, the atmospheric transmission between the target/background and the receiver, the reflectivity of the target/background, and the minimum detectable signal.

Output Products

TAWS and NOWS provide tabular and graphic output products that can be tailored to users' specific needs. Several different table types are available, with a user-specified comment line for each one. Several different graph types are available; users can adjust graph labels, scaling, fonts, and colors. All output products can be printed or saved to standard file formats. Figures 8 through 10 show sample output products.

Figure 8 is a solar/lunar events graph, created with a TAWS illumination analysis. This graph shows the daylight, twilight, moonlight, and true night periods for a period of seven days.

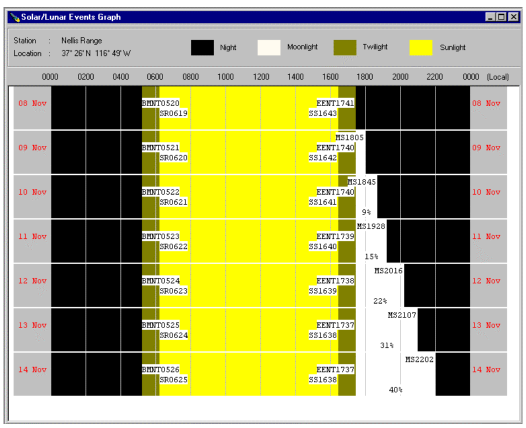

Figure 8. Solar/Lunar Events Graph

Figure 9 is a plot of IR detection range for one target against two possible backgrounds, created with a TAWS map-based analysis.

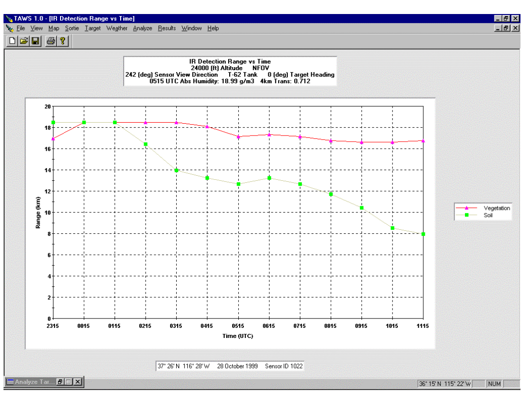

Figure 9. IR Detection Range as a Function of Time Graph

Figure 10 is a plot of IR detection range for one target given three possible sensor elevations, created with a TAWS point-based analysis.

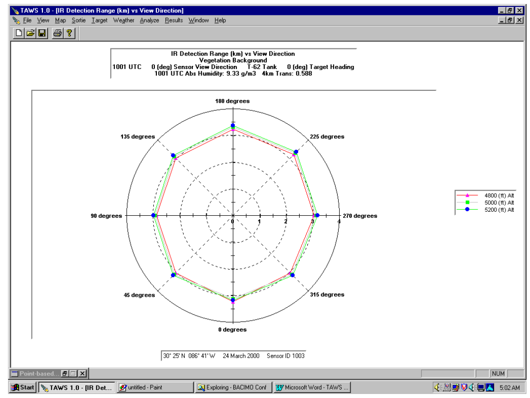

Figure 10. IR Detection Range as a Function of Azimuth Graph

Software Delivery Schedule

TAWS and NOWS aim for incremental software development and rapid response to changing user requirements. TAWS Version 2 and NOWS Version 6 are currently in production. The following table shows the TAWS and NOWS delivery history and schedule.

Table 1

NOWS Release	Date
NOWS Version 1.0	May 1995
NOWS Version 2.0	November 1995
NOWS Version 3.0	December 1996
NOWS Version 4.0	October 1997
NOWS Version 5.0	April 1999
NOWS Version 6.0	June 2000
TAWS Release	**Date**
TAWS Beta	June 1999
TAWS Version 1.0	November 1999
TAWS Version 2.0	June 2000
TAWS Version 3.0	(January 2001)
TAWS Version 4.0	(August 2001)

References

Bangert, J.A., 1998a: A Portable Computer Source-Code Module for Computing Accurate Times of Lunar and Solar Phenomena. U.S. Naval Observatory, Astronomical Applications Department Revised Technical Note.

Bangert, J.A., 1998b: Solar-Lunar Almanac Core (SLAC) Software User's Guide Version 1.1. U.S. Naval Observatory, Astronomical Applications Department.

DeFries. R.S., and J.R.G. Townshend, 1994a: "NDVI-Derived Land Cover Classification at Global Scales," International Journal of Remote Sensing, 15:3567-3586. Special Issue on Global Data Sets.

Hering, W.S., 1981: An Operational Technique for Estimating Visible Spectrum Contrast Transmittance. AFGL-TR-81-0198. University of California, San Diego, Scripps Institution of Oceanography, Visibility Laboratory, CA.

Hering, W.S., 1983: Analytic Techniques for Estimating Visible Image Transmission Properties of the Atmosphere. AFGL-TR-83-0236. University of California, San Diego, Scripps Institution of Oceanography, Visibility Laboratory, CA.

Hering, W.S., and R.W. Johnson, 1984: The FASCAT Model Performance Under Fractional Cloud Conditions and Related Studies. AFGL-TR-84-0168. University of California, San Diego, Scripps Institution of Oceanography, Visibility Laboratory, CA.

Johnson, K.R., 1991: Technical Reference Guide for TCM2. Georgia Tech Research Institute, Georgia Institute of Technology, Atlanta, GA.

Johnson, K., A. Curran, D. Less, D. Levanen, E. Marttila, T. Gonda, and J. Jones, 1998: MuSES: A New Heat and Signature Management Design Tool for Virtual Prototyping. Ninth Annual Ground Target Modeling & Validation Conference, Houghton, MI. ThermoAnalytics, Inc., Calumet, MI, and US Army TACOM, Warren, MI.

Kneizys, F.X., E.P. Shettle, W.O. Gallery, J.H. Chetwynd, L.W. Abreu, J.E.A. Selby, S.A. Clough, and R.W. Fenn, 1983: Atmospheric Transmittance/Radiance: Computer Code LOWTRAN 6. AFGL-TR-83-0187. Air Force Geophysics Laboratory, Hanscom AFB, MA. ADA137786.

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