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Data Fusion Processing for the Multi-Spectral Sensor Surveillance System (M4S)

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ABSTRACT

The Multi-Spectral Sensor Surveillance System (M4S) is a multi-year ONR-sponsored program to transition mature sensor and data fusion technology into existing and/or near-future airborne surveillance platforms. A study phase and on-board sensor data fusion concept-of-proof demonstration have been completed in 1997. This paper describes the data fusion concepts, architecture, and algorithms that have been designed and demonstrated in these efforts.

The data fusion architecture selected for M4S is a distributed design in which each on-board sensor sub-system is equipped with a single-sensor tracking unit satisfying all the sensor-specific tracking needs in addition to required sensor data processing capability. Thus scan-to-scan, or frame-to-frame correlation is basically resolved on a single-sensor basis, and the outputs of each sensor-subsystem are typically single-sensor tracks, or tracklets, i.e., stochastically independent fractions of tracks. Those outputs are then fed into a centralized multi-sensor, data fusion process that performs track-to-track association analysis and fuses appropriate single-sensor tracks into multiple-sensor tracks.

In this way, each sensor sub-system provides target information complementary to each other as well as reinforcing each other, in terms of both target identification and target localization, so that the central data fusion process may produce a best picture of each target of interest. This system architecture also allows each sensor-specific tracker to temporarily lose hold of some targets but to re-acquire them later, yet to maintain continuous target recognition.

This data fusion process is also connected, through an external communication network, to off-board intelligence and surveillance sources, such as Rivet Joint, AWACS, U2, JSTARS, etc., to provide the system with a complete tactical picture. This distributed architecture requires each on-board sensor sub-

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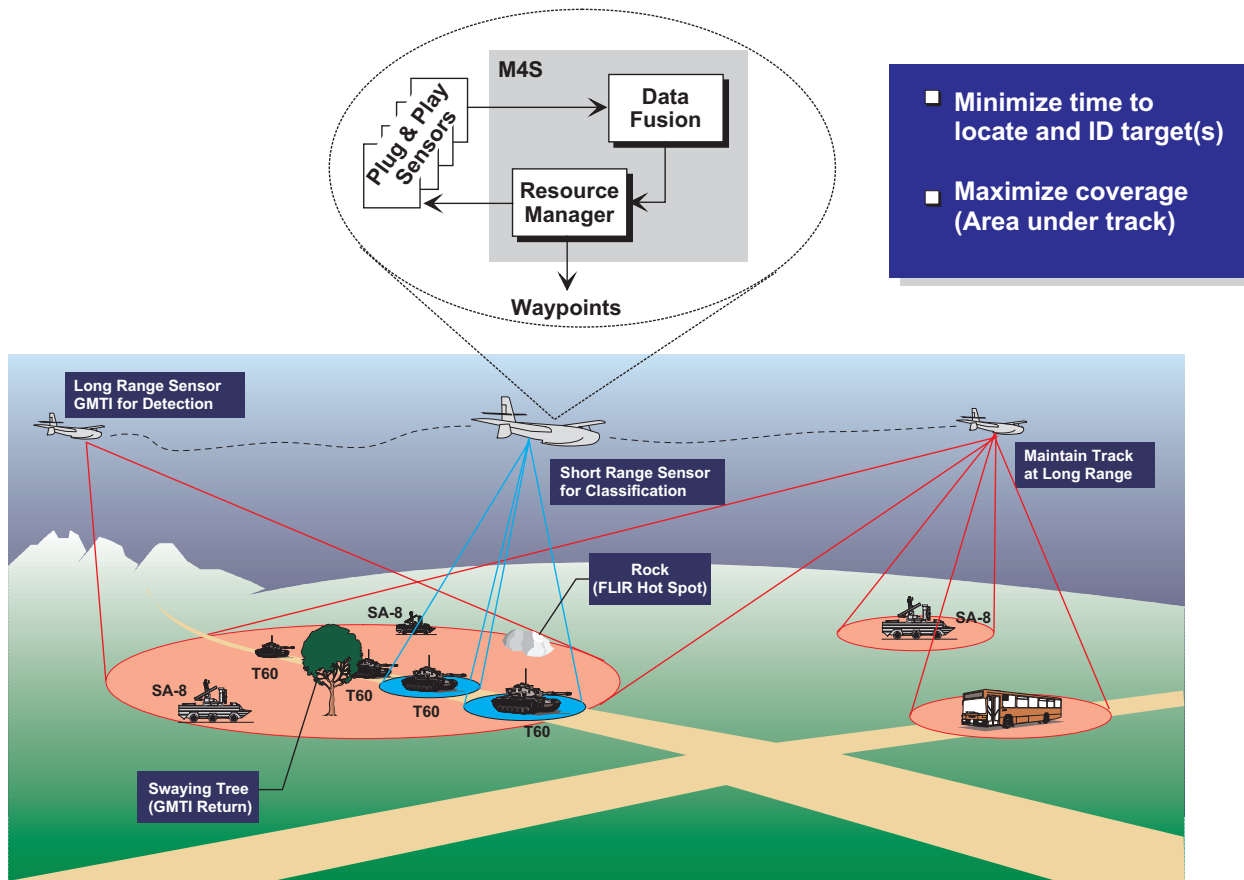
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1.0 INTRODUCTION

A new world order is changing tactical threat perspectives and operations. New pressures to minimize force exposure and attrition while improving asset effectiveness in limited conflict engagements are key requirements behind this tactical philosophy. Because of likely limited warfare in confined battle areas, situation awareness, combat identification friend or foe, secure C³ on the move, and re-locatable target location systems will be required to support these needs. The Navy has a pervasive and expanded role in this new tactical scenario. Littoral Warfare and force projection ashore, in concert with other force structures, is vital to new tactical scenarios. Shipboard Surveillance will be the key operational factor in Joint Mission Littoral Warfare.

A powerful approach to Littoral surveillance is the deployment of Unmanned Air Vehicles (UAVs) or other airborne platforms equipped with multi-spectral surveillance capability. An aircraft, launched from land or a Carrier Battle Group, provides critical, real-time intelligence information necessary for target surveillance, location, identification, battle planning and post-strike Battle Damage Assessment (BDA). Figure 1.1 depicts the concept of operations for a Multi-Spectral Sensor Surveillance System (M4S). In this scenario a single air vehicle outfitted with multi-spectral sensors is able to detect critical targets through fusion of contact reports received from off-board sensors and its own GMTI Radar. Armed with this information the vehicle and its sensors are tasked to further classify and identify these targets utilizing its short-range sensors. Fusing the information from both the long and short-range sensors allows the M4S to continue to maintain track on these critical targets even at long range.



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Figure 1.1
M4S Concept of Operations

To demonstrate this capability, ONR has sponsored a multi-year program to transition notional sensors and data fusion technology into existing or near-future airborne surveillance platforms. The objective of this program is to prove the ability of enhanced data fusion algorithms to detect, identify, and track targets with improved detection probability and greater position and identification accuracy in a reduced amount of time with fewer false alarms using multiple dissimilar on-board sensors and off-board information.

The team of ONR, Litton Applied Technology, Raytheon Systems Company, QuesTech, CSCI, and SPAWAR Systems Center has completed a study phase and on and off-board sensor data fusion concept-of-proof demonstration. The primary technical objective of this team is to develop a design architecture and enhanced data fusion algorithms that support the goal of critical target identification in a reduced time-line.

The data fusion architecture selected for M4S is a distributed design in which each on-board sensor sub-system is equipped with a single-sensor tracking unit satisfying all the sensor-specific tracking needs in addition to required sensor data processing capability. Thus scan-to-scan, or frame-to-frame correlation is basically resolved on a single-sensor basis. These outputs are then fed into a centralized multi-sensor, data fusion process that performs track-to-track association analysis and fuses appropriate single-sensor tracks into multiple-sensor tracks. In this way, each sensor sub-system provides target information that is both complementary and reinforcing to the others so that the central data fusion process may produce a best picture of each target of interest. This system architecture also allows each sensor-specific tracker to temporarily lose hold of some targets yet the overall system can maintain continuous target recognition.

This data fusion process is also connected, through an external communication network, to off-board intelligence and surveillance sources, such as Rivet Joint, AWACS, U2, JSTARS, etc., to provide the system with a complete tactical picture. This distributed architecture requires each on-board sensor sub-system to perform more or less autonomously. In order to assist single-sensor track initiation processes, however, the central data fusion process provides feedback tracks to the sensor sub-systems, as well as cross-sensor or off-board cueing instructions.

Four notional sensors, ESM, radar, EO/IR, and laser sensors have been chosen for on-board sensors that provide a unique combination of electromagnetic and optical, and passive and active, sensing. The distributed system architecture, however, allows us to expand or modify this sensor suite without any significant modification to the system design, in a more or less plug-n-play fashion.

The M4S proof-of-concept demonstration was successfully completed in 1997 showing the full potential of the system concept, using emulated on-board sensors and off-board sources. In the coming years, development of concepts for on-board, on-line, sensor and platform resource management will take place, as well as switching emulated sensors to real sensors, with the goal of demonstrating M4S on an airborne platform.

2.0 DISTRIBUTED DATA FUSION ARCHITECTURE FOR M4S

The choice between a distributed or centralized architecture is one of the most important design decisions to be made in the development of any dissimilar source data fusion system. A distributed fusion architecture is characterized by a number of parallel processing channels each of which deals with a subset of the fusion problem. These processing channels are then combined to generate an integrated track database. A centralized fusion architecture is essentially the opposite - the entire fusion problem is dealt with as a single entity. Each of these alternatives offers specific advantages and disadvantages, and the selection requires a careful consideration of the intended application and the nature of the input sensor reports.

As described in the previous section, the objective of M4S is to prove the ability of enhanced data fusion algorithms to detect, identify, and track targets with improved detection probability and greater position and identification accuracy in a reduced amount of time using multiple dissimilar on-board. For M4S we did not limit ourselves to the exact capabilities of existing sensors, but considered the probable evolution of sensor capabilities to the year 2005. The specific sensors types considered include a multi-mode radar, an infrared sensor, an ELINT system, and a continuous wave laser capable of detecting vehicle vibrations. Additionally, we assumed the availability of off-board sensor data provide by over communication links to the M4S platform.

The notional radar is similar to a potential variant of the Raytheon AN/APS-137B (V) 5 and is capable of operating in the following modes:

- GMTI (Ground Moving Target Indicator) for the detection of moving ground targets,
- PPI (Plan Position Indicator mode) for the detection of ships and coast lines,
- SAR (Synthetic Aperture Radar) for imaging and classifying fixed objects, and
- Inverse- Synthetic Aperture Radar (ISAR) for imaging moving objects such as ships.

The notional IR sensor has capabilities similar to the Raytheon FLIR developed for the LAMPS helicopter. It is capable of operating in both a wide field of view for search and detection, and narrow field of view for target classification.

The assumed ESM system for M4S is essentially the PLAID system being developed by Litton Applied Technology for Wright Laboratories. Similarly, the LASER is similar to a system developed by Litton Laser Systems.

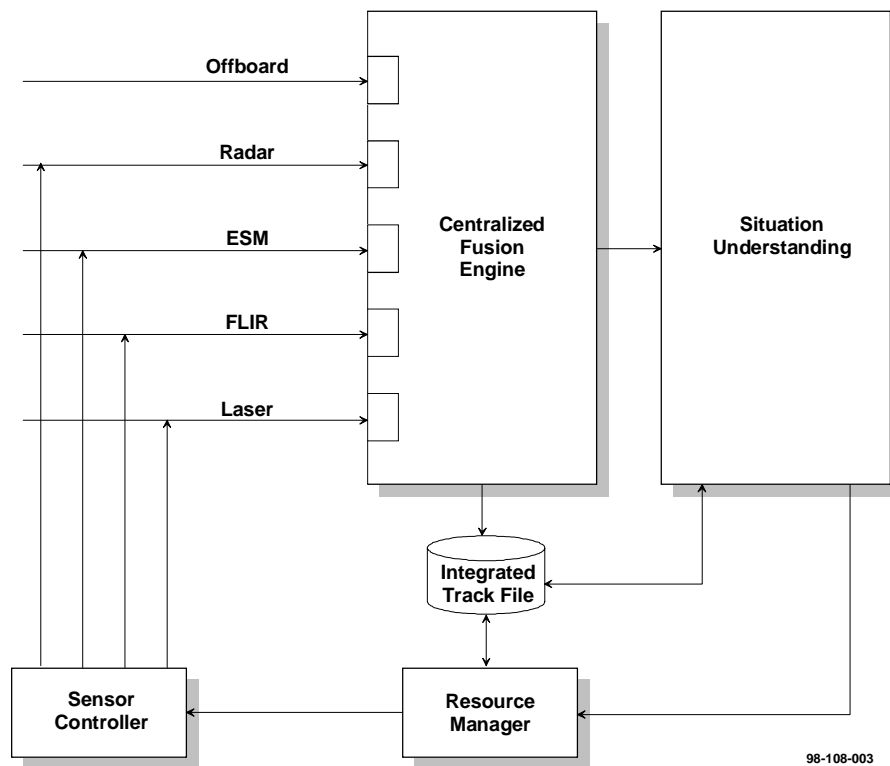
The specific features, reported by these hypothesized sensor systems, are listed in detail in Table 2.1. The selected sensor systems are highly complimentary in nature and there is significant potential for synergy. For example, there is a mixture of active (RADAR and LASER) systems and passive (ESM and FLIR) systems. The detection range varies from an assumed 1000 nm for off-board reporting, to 80 nm from ESM, to 2 nm for the LASER, and the notional data rates vary from almost two hundred report per minute to about one per minute.

Sensor	Geo-positional data reported	Reported Features	Range at 5000' Alt	Nominal Data Rate	Comments
Off-Board Sensor Data	Time of Intercept (TOI) Latitude/Longitude Measurement Error	Emitter identification (ELNOT) Emitter parameters (PRI, RF, PW,SP) Discrete Attributes (e.g., Name, WACBE, platform type, etc.)	1000 nm	180 intercepts/minute	Wide area surveillance data broadcast by a collection of remote platforms. A mixture of various sensor systems feed this broadcast.
ESM	Time of Intercept (TOI) Latitude/Longitude Measurement Error	Emitter identification (ELNOT) Emitter parameters (PRI, RF, PW,SP)	80 nm	180 intercepts/minute	Requires target emission.
Radar in GMTI mode	TOI Sensor location Slant range, azimuth Velocity vector Measurement Error	Sensor assigned track number Wheeled / Tracked discrimination Aircraft propulsion discrimination	75 nm	90 tracks / minute	Assume 1% false target rate Assume aberrancy rate of 1% Assume high track fragmentation
Radar in PPI mode	as above	Sensor-assigned track number	75 nm	90 tracks / minute	as above
Radar in SAR / ISAR mode	as above	Sensor-assigned track number Target type identification with prob. Image, Size, Shape, etc.	65 nm	1 track / minute	Assume no false targets
IR Search Mode	TOI, Sensor location Azimuth Measurement Error	Sensor-assigned track number Target type identification with prob. Image, Size, Shape, etc.	10 nm	10 reportable object / minute	Sensor processing determines reportable objects Assume wide Field of view
IR Classification Mode	as above	as above	10 nm	1 reportable object / minute	As above.
Laser Vibration	TOI, Sensor location Slant range, azimuth Velocity vector Measurement Error	Sensor assigned track number Target type identification with prob. Vibration frequency meas.	2 nm	1 track / minute	Assume slewed with IR sensor in Classification mode

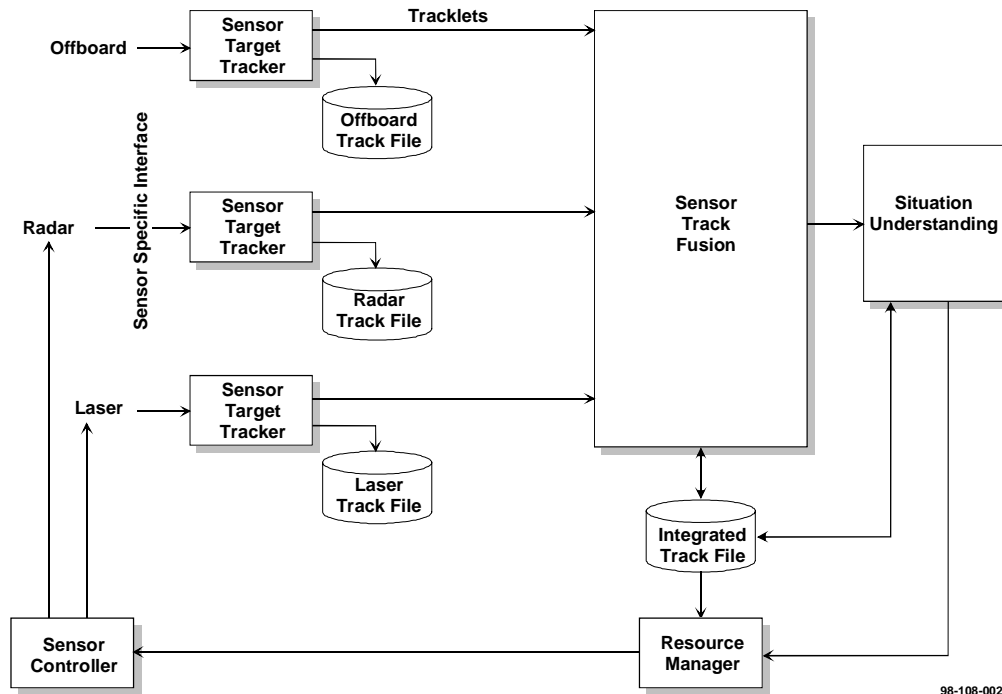
Table 2.1
Assumed Sensor Reporting Characteristics for M4S Sensors

Additionally, the reported features are highly dependent on the specific sensor and mode, and include only the presence of a target (RADAR in PPI mode), images (SAR, IRAR, and FLIR), ESM parametrics, and acoustic vibration signature data.

For the M4S program, we considered both the distributed and centralized candidate fusion architectures indicated in Figure 2.1. The centralized fusion architecture has three logical components: a fusion engine, a situation understanding function, and a resource manager. The fusion engine takes all incoming sensor reports, combines them into tracks, and draws inferences on these tracks. The situation awareness function evaluates aggregations of individual tracks, and attempts to understand the significance of the state and location of the aggregate of tracks. The resource manager, in contrast, exploits the knowledge captured by the fusion engine, and tasks the individual sensors available to the system to achieve and maintain tracks.



Centralized Fusion Architecture



Distributed Fusion Architecture

Figure 2.1
Centralized and Distributed Fusion Architectures considered for M4S

In the distributed alternative, the fusion engine is split into a series of single sensor target trackers, and the multi-sensor track fuser. Thus, four sequential processing steps perform differing levels of fusion: the sensor target tracker, the track fuser, situation understanding, and resource management. These functions roughly correspond to the definition for Levels 1 through 4 data fusion as defined by the Joint Director's of Laboratories Data Fusion sub panel.

The sensor target trackers correlate information provided by a single sensor or a collection of similar sensors. To do this, the sensor target tracker exploits specific features generated by a sensor, including position, to construct pure output target tracks. For example, for the ESM sensor target tracker, the information specific features include those listed in Table 2-1: RF, PRI, SP, and PW. Since each sensor target tracker can exploit similar features to aid in its correlation decision, its reliability is significantly enhanced.

The output of this stage is a "tracklet." The notion of a tracklet is an essential feature of the distributed architecture. Tracklets are small, stochastically independent portions of a track made up of a sequence of contact reports from single sensor (or sensor type). Each tracklet has an associated tracker number together with whatever features have been observed by the sensor. Tracklets have temporal extent, and thus, a derived velocity component.

The second stage of the distributed fusion process is the multi-sensor track fuser. The multi-sensor track fuser receives a sequence of tracklets from sensor target trackers, and correlates these tracklets together, largely because of the track number provided by the sensor target tracker. In this fashion, the fuser reconstructs the tracks maintained by the sensor target tracker.

The challenge of the track fuser, then is to determine when a given target track is represented in the data stream by more than one target tracker. The sensor track fuser exploits the temporal extent of the tracklets to increase the reliability of track correlation. Feasibility tables also support the sensor track fuser. These tables specify which combinations of sensor features are feasibly on platforms or objects of interest.

There is some research to indicate that a centralized fusion architecture is optimal under a number of circumstances. See for example references [2] and [3]. For M4S, however, we have selected a distributed fusion architecture. The reasons for this decision are driven by a number of implementation considerations. These include:

Computational resources are a significant concern in the M4S environment. It is important that the system keep up with the sensor data with no significant data loss. By distributing the processing, the problem of data loss is effectively managed. The distributed architecture allows us to host the sensor target trackers on separate processors from the fusion processor. Each of these processors can be sized to meet the specific processing required of that data path. Moreover, the tracklet approach of inter-processor communications allows the fusion processor to query the sensor tracker for data when it is free to accept more data. The query – response approach automatically throttle the input rate to the sensor fuser to the rate at which it can process the data. In the interim, the sensor target tracker can continue to extend the temporal extent of tracklets.

The distributed architecture allows plug and play capability. Each sensor target tracker can be designed to exploit the special features generated by each sensor. This capability allows for the implementation of algorithms with very effective correlation of similar source data. Moreover, each sensor target tracker can convert the input sensor stream into a standard tracklet format accepted by the sensor fuser. The query response approach automatically prevents the sensor fuser from being saturated with data provided by the new feed. Thus, a new source of information can be effectively added to the sensor fuser in a plug and play fashion.

3.0 SENSOR TRACK SOFTWARE

As mentioned above, each sensor sub-system has its own sensor signal processor and a single-sensor tracker, as well as necessary sensor control mechanism. As shown in Figure 3.1, a rather standard or traditional tracking system architecture was chosen for each single-sensor tracker. This software processes a frame (or scan) of sensor detections to maintain single-sensor tracks and outputs those tracks, judged to be sufficiently mature, to the multi-sensor data fusion process.

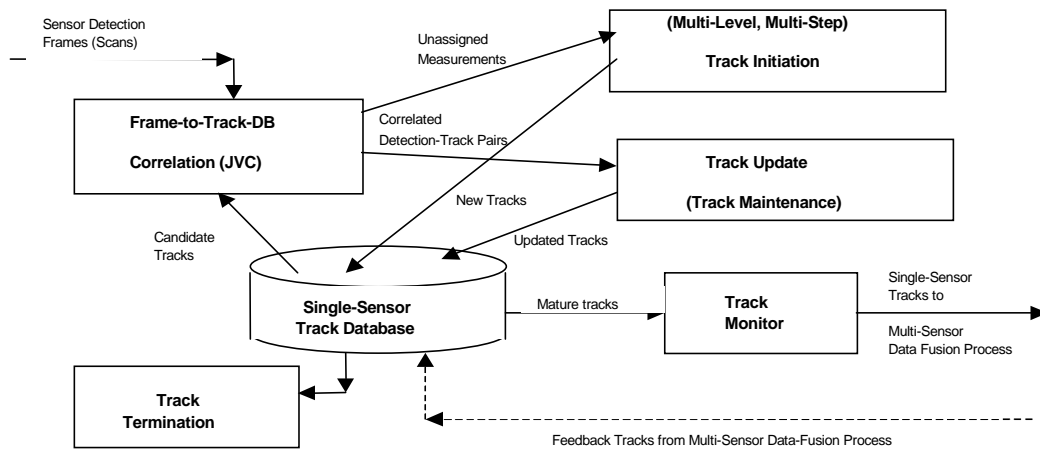
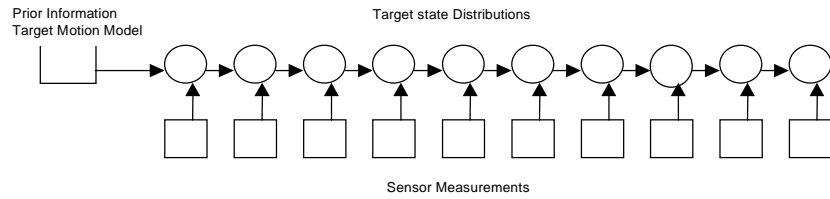


Figure 3.1
Single-Sensor Tracker Software

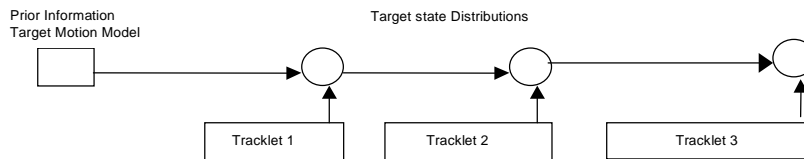
Each frame of detections (or reports) from the sensor signal processor is input into the frame-to-track correlator to obtain the frame-wise optimal report-to-track correlation (association). For this purpose, the JVC assignment algorithm, known to be the most efficient, is used. The track update process updates the associated report-to-track pairs and unassociated reports are fed into the track initiation process. The track initiation algorithm is designed to be generally multi-level and multi-step. The track termination process, another standard component, is also used to terminate tracks that are not updated more than a specified time period. The tracks that are in the track database and that are judged to be “mature” tracks by the track monitor process will be fed into the multi-sensor data-fusion process. In order to alleviate the track initiation function, multi-sensor tracks may be fed back to each single-sensor tracker as necessary.

The tracks that are judged to be “mature” enough are output to the multi-sensor, data-fusion process, through a track monitor. When a track has accumulated a large number of reports (or measurements) from each sensor, it is not efficient to move the whole track as a set. An alternative is to represent the track by the target state distribution at the most recent update time. By doing so, we reduce the necessary internal communication bandwidth significantly, but, at the same time, we may lose crucial information necessary to fuse information from multiple sensors. Therefore, a compromise was made by aggregating information contained in an appropriate number of consecutive sensor reports. Those subsets of sensor reports are called *tracklets*, as a small aggregation of temporally local sets of sensor reports. The length of each tracklets can be determined by the track monitor of each sensor sub-system based on the sensor revisit rate, the target dynamics, and designed internal communication bandwidth. In other words, these tracklets have been chosen as a primary unit of communication among all the sub-systems within the overall data fusion systems.

Each tracklet is an aggregation of consecutive sensor reports. There are several approaches to obtain the sufficient statistics for each tracklet. For the M4S data fusion system, the *decorrelation* approach was selected. In this approach, tracklet statistics are calculated from the target state distribution at the end of the last tracklet and from the end of the current tracklet. This is illustrated in Figure 3.2. As you can see in this figure each sensor report (or detection) is shown by a box, and each target state estimate at a given time is illustrated as a circle which is an accumulation of information contained in all the reports up to that point. In order to calculate the statistics of a given tracklet, we subtract the information accumulated into the target state distribution (up to the last time a tracklet was produced) from the current target state distribution. This results in only “new” information being added to this track.



(i) Standard Tracking (Filtering) Process



(ii) Tracklet Representation

Figure 3.2
Concept of Tracklets

A target state includes ordinary position-velocity geolocational state. But it may also include other components that are required or otherwise beneficial for the purpose of single-sensor tracking. For example, for the EO/IR sensor sub-system, the size-shape parameters of the target images and/or the other state variables related to the target classification/recognition, can be included. As discussed later in the description of the M4S demonstration, the size-related parameter states are used to simulate non-geolocational data for the imaging sensors, such as the SAR/ISAR-mode radar and the EO/IR sensor. Similarly, the measured vibration spectral parameters are used to simulate the laser sensor's non-geolocational measurements.

4.0 MULTI-SENSOR, ON-BOARD/OFF-BOARD DATA FUSION

There are a number of enabling algorithms required for the Multi-Sensor Track Fuser to perform its function. These algorithms include:

A statistical tracker. The tracker, a Kalman Filter algorithm, is required to refine a track's location at a specified time, to project the track location into the future, and to estimate the tracks historical location. The tracker also estimates the velocity vector at an arbitrary time, as well provides the uncertainty (covariance) in position and velocity. The functions are required to support correlation and track to track association decisions. The algorithm is based on the Maneuvering Target Statistical Tracker (MTST) algorithm as described in [8]. The Multi-Sensor Track Fuser processes the tracklets sent from the Sensor Tracker that is a part of each sensor subsystem.

Track correlation. A track correlation function is required to combine tracklets from a given sensor target tracker into logical tracks. The Sensor Tracker of each sensor sub-system performs single-sensor frame-to-frame correlation and the results are provided as the unique track number attached to each single-sensor tracklet. However, since many of the sensor target trackers are assumed to generate high fragmentation rates, this function is also required to reduce the number of track fragments. The statistical tracker is an important element in track correlation. It determined when to tracklets or track fragments are position feasible.

Track-to-Track association. This is the fundamental algorithm in the sensor track fuser. It determines when two tracks from different sources represent the same physical object. To accomplish this, the track-to-track association algorithm compares the entire track estimates generated by the statistical tracker. It also uses feasibility tables employed in threat inferencing to determine which combinations of report features are feasible. The Sensor Track Fuser Process maintains those multi-sensor fused tracks as a two-level structure as illustrated in Figure 4.1.

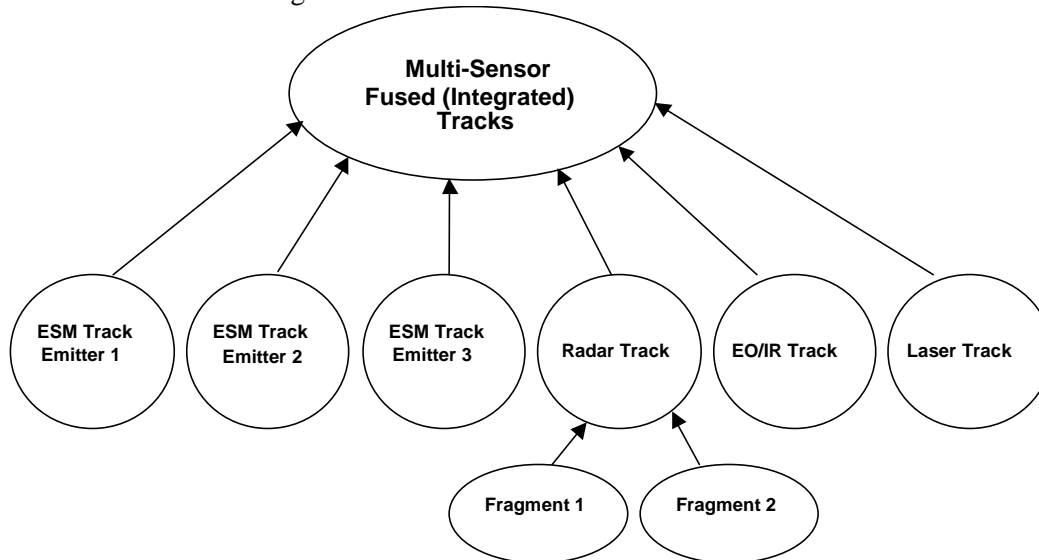


Figure 4.1
Multi-Sensor Fused (Integrated) Tracks Data Structure

A multi-sensor, fused track consists of the union of all the tracklets contained in its component tracks as shown in Figure 4.1. However, the Sensor Track Fuser Process maintains both the fused track, called an integrated track, and its component tracks, as independent tracks. For example, suppose that a fused track has all the component tracks shown in Figure 4.1, and then, that one of the sensor subsystem sends a new tracklet into one of the component tracks, say the ESM track that tracks the first emitter of the platform target being tracked. Then, the Sensor Track Fuser updates the first ESM track by this new ESM tracklet, and at the same time, the same tracklet is sent to the fused (integrated) track and is used to update the fused track. By maintaining this double structure, it is able to maintain the component-wise picture as well as fused picture at all the time, to enable flexible data fusion operations as necessary. As shown in Figure 4.1., in general, any component track may contain its fragments that are put together by the Sensor Track Fuser.

Threat Inferencing. The purpose of threat inferencing is to evaluate the collection of features, from the various dissimilar sensors reporting on a track, to infer more about the identity or function of an object. Threat inferencing exploit tables that define the observable features associated with each reportable object of interest. These feature can include size and shape (which are partially observed by imaging sensors), physical characteristics (wheeled or tracked, etc.), and emissions (which are partially observed by ESM and acoustic sensors). These tables indicate which combinations of features are feasible (used to track-to-track association) and well as to infer additional information about a multi-sensor track.

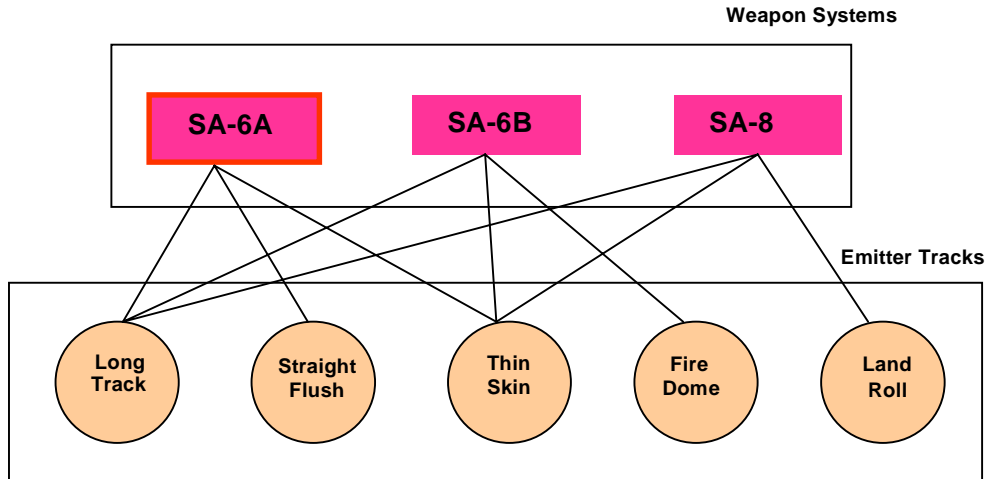
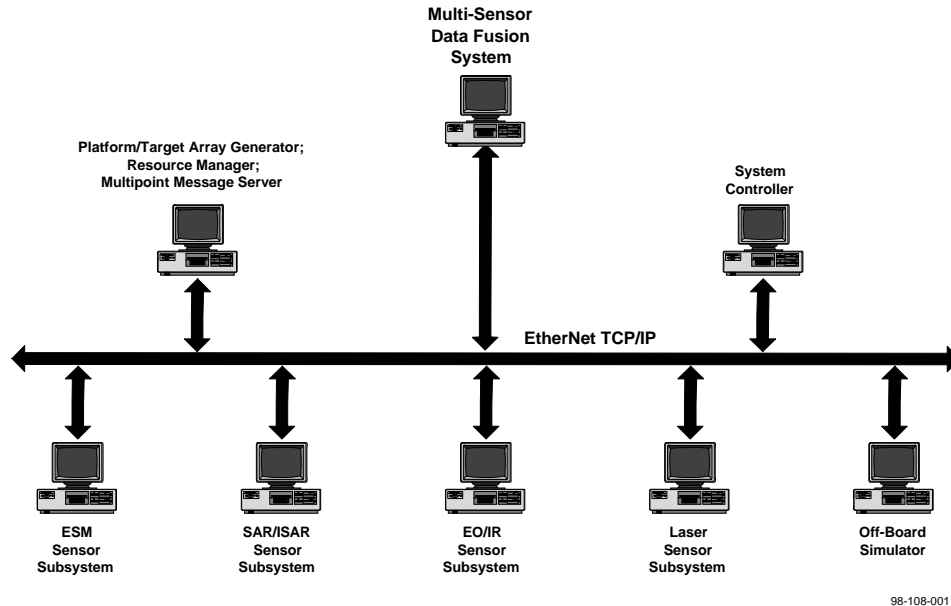


Figure 4.2
Weapon System Threat Inferencing

Figure 4.2. shows an example of threat inferencing that takes place inside the Sensor Track Fuser. Figure 4.2 shows the three weapon systems and the set of emitters associated with each system. For example, SA-8 system has three emitters, Long Track, Thin Skin, and Land Roll. The Sensor Track Fuser maintains such relations in Weapon System Database so that, from a given set of emitter tracks, for example, from Long Track, Thin Skin, and Fire Dome, the existence of Weapon System SA-6B is deduced. The Radar subsystem, using its SAR and ISAR mode, can provide image attribute data, as well as wheeled/tracked declaration attributes from the GMTI mode. The EO/IR subsystem can provide additional image attribute data, while the Laser subsystem can identify the engine types from the vibration spectrum analysis. Those additional attributes are also used by this threat inferencing to determine the target type classification.

5.0 SYSTEM DEMONSTRATION EXAMPLE

The M4S project utilizes a System Integration Laboratory (SIL) to provide an effective test, evaluation and demonstration environment. The M4S SIL is constructed of eight separate high performance PCs running Microsoft Windows NT, which are connected together through an Ethernet network. Each PC is responsible for providing specific M4S functionality by hosting individual software components to create an integrated system. The SIL is configured with four PCs housing specific sensor subsystems (ESM, Radar, FLIR/EO, Laser), an off-board simulator PC, a system control PC, a multi-sensor data fusion PC, and a support PC which provides platform and target generation, resource management activities and a multipoint messaging service. The SIL configuration is illustrated in Figure 5.1.



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Figure 5.1
M4S Demonstration Configuration

The M4S system has been developed to support an improvement in the success for tactical and surveillance missions through the process of multi-sensor data fusion and a closed loop mode of operation. Scenarios have been developed to measure the M4S system’s effectiveness for situations such as ocean surveillance, armored column, and site assessment activities. Due to the flexibility of the architecture, M4S supports a “plug and play” type capability to allow for a suite of sensors that will provide effective land, afloat and air coverage. The M4S demonstration system is illustrated in Figure 5.2.

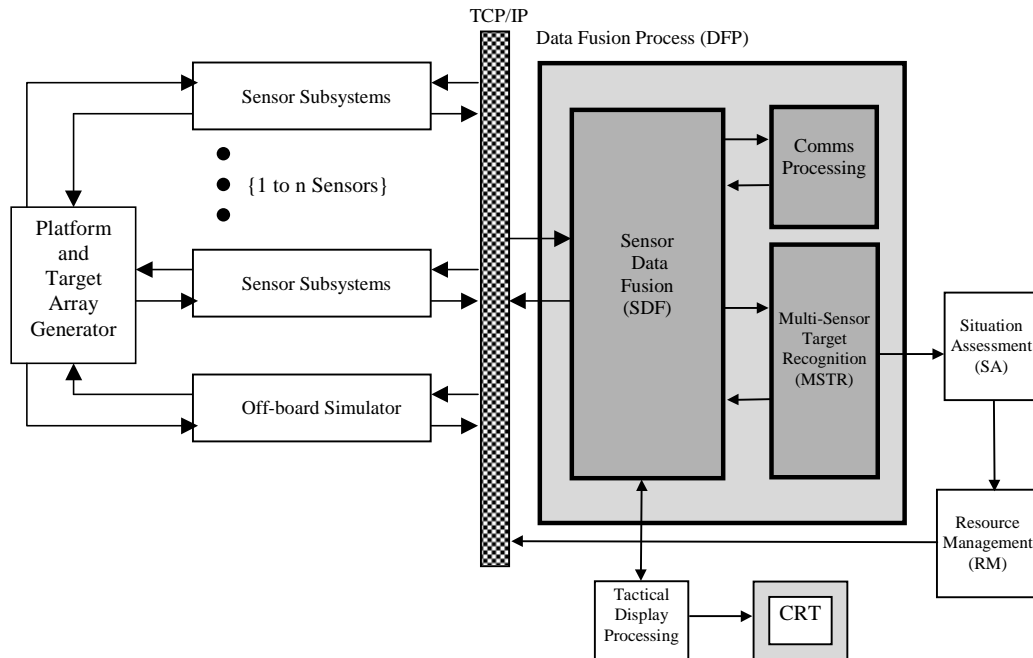


Figure 5.2
M4S Demonstration System

The M4S ocean surveillance scenario starts with the M4S platform beginning its flight from the United Arab Emirates (UAE) on a mission to detect, classify and localize the position of all surface traffic in the Strait of Hormuz. Slightly after takeoff, the on-board ESM sensor detects ten different radars operating in the South East portion of the strait. Through the first stages of data fusion, M4S performs track-to-track associations to link associated emitters that belong to common platforms together, reducing the situation to five unidentified tracks. The five tracks are determined to be categorized as two hostile and three unknown ships. The M4S platform is then directed North by resource management activities to provide ample sensor coverage by the on-board radar sensor. The ISAR mode is used to acquire the two hostile ships in an attempt to identify their ship type. Figure 5.3 shows a visual presentation from the multi-sensor fusion application at the initial stage of the ocean surveillance scenario.



Figure 5.3
Ocean Surveillance Scenario Start

After a successful classification of two hostile cruiser class ships determined from the fusion of the ESM and ISAR detections, the M4S platform performs an assessment of the situation to determine the next course of action. Realizing the tracks that have yet to be identified and the suite of sensors M4S has available, the platform is directed to fly East first for positioning and then South to intercept the course of the nearest unidentified track. Using the FLIR/EO and Laser sensors a hostile patrol boat is both identified and pinpointed for position through the use of multi-sensor data fusion. The combination of ESM detected emissions, FLIR/EO imagery features and Laser detected vibration frequencies are associated to provide a high confidence classification as well as an accurate position with very little uncertainty. The radar is allocated in a PPI search mode to maintain track on the hostile patrol boat while an assessment of the situation is performed to direct the platform towards the next unidentified track by the resource manager. Figure 5.4 shows an example of a cruiser class ship with fused information from the on-board ESM, radar, FLIR/EO and Laser sensors.



Figure 5.4
Multi-sensor Fused Track

Situation assessment and resource management logic provides for automated platform flight rerouting and dynamic sensor allocation during the mission. The platform is therefore able to continue in this mode of operation autonomously due to the M4S closed loop architecture to successfully complete it's mission. The ocean surveillance scenario ends with the M4S platform providing accurate tracking and classification of five separate tracks: two hostile cruisers, one hostile patrol boat and two neutral oil tankers. The two following figures show visually the difference between a scenario that contains the M4S level of multi-sensor data fusion and a scenario that doesn't. Figure 5.5 shows a fused picture with five well identified tracks with little uncertainty of their position.



Figure 5.5
Fused Ocean Surveillance Scenario

Unlike Figure 5.5, Figure 5.6 illustrates a picture that contains twenty-seven different tracks with a high level of uncertainty represented by the 90% containment ellipses that are drawn for each track.



Figure 5.6
Nonfused Ocean Surveillance Scenario

6.0 YEAR-TWO EXTENSIONS

The next step in the proof of concept process for M4S will be to concentrate efforts in closing the communications loop between the data fusion process and the sensors. In support of this, the M4S team will develop algorithms and techniques for improved Situation Awareness and Resource Management. Multi-sensor data fusion results coupled with area specific Electron Order of Battle (EOB) data will be used to create a tactical picture that will drive resource (air vehicle and sensors) management decisions. Figure 6.1 captures a scenario in which five tanks and two SA8s are identified by the sensors and the data fusion process in an area. Further analysis of this data and the EOB results in an aggregated Situation Awareness picture showing their area of influence. Given this information we may assume a level of air coverage associated with this column of tanks that may preclude the system from collecting closer range sensor information in this area. The resource management functions could then task the sensors to collect data on other targets of interest.

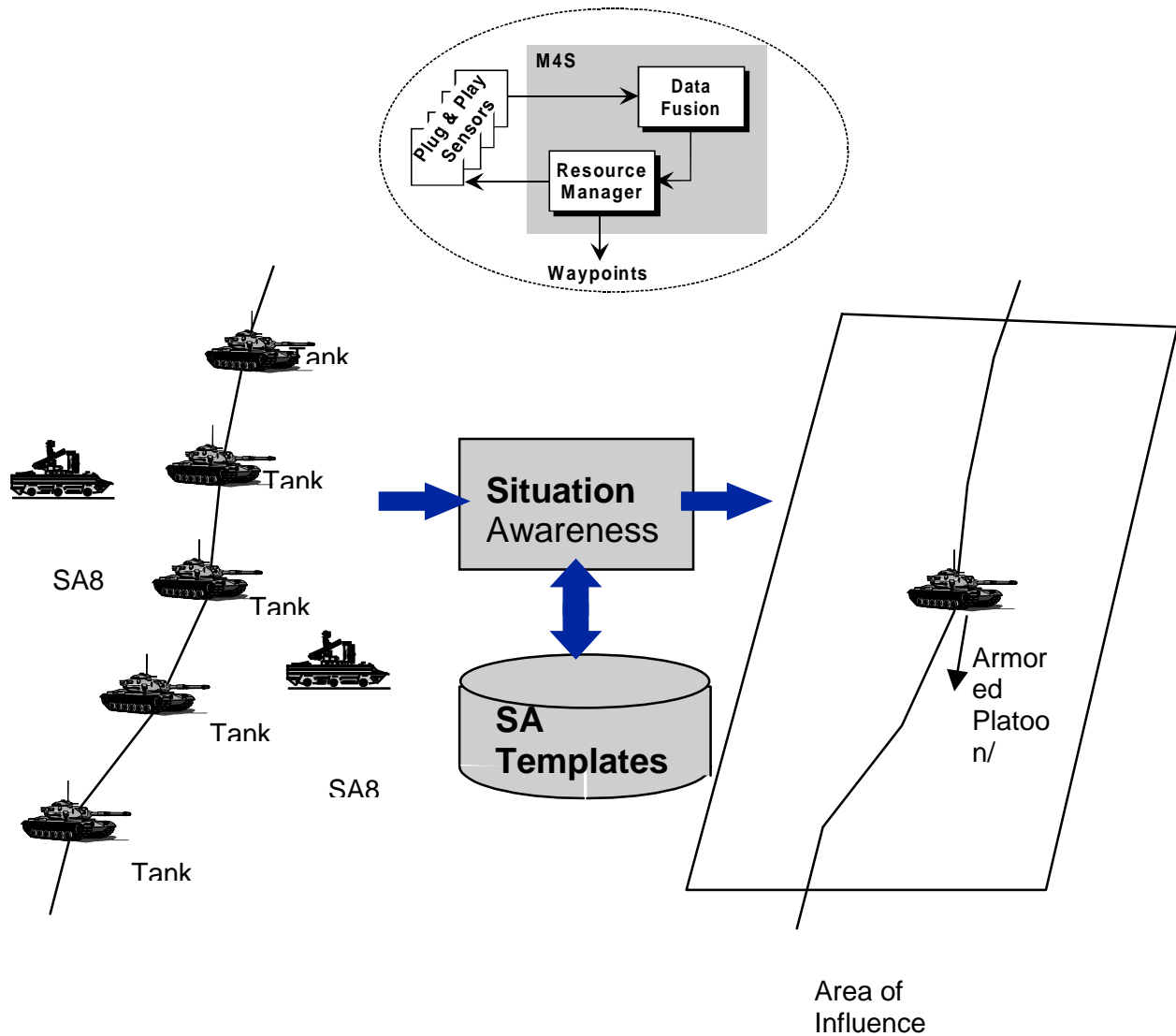


Figure 6.1
Situation Awareness and Resource Management Concepts

By closing the loop and developing the capability to task the sensors, we can further identify the best usage of our notional sensors to further improve the systems ability to accurately identify targets of interest in a shorter time-line.

With the completion of the closed loop M4S architecture, further laboratory testing can be done to measure the effectiveness of the correlation and sensor tasking algorithms. While the M4S SIL can continue to be used to test various combinations of sensors, the real test will be to interface M4S with real sensors on an airborne platform. The MOE analysis collected from the first year of testing is

encouraging. Completing the architecture by adding Situation Awareness and a Resource Manager should further serve to improve the systems ability to quickly and efficiently localize and identify tracks. Armed with this data, evaluating M4S on an airborne platform will continue to show how current and near-term sensor systems can be made even more efficient and useful without any hardware modifications. Coupling these sensor systems with M4S will not only allow us to make better use of current systems but will aid our forces in more effectively locating and identifying critical targets.

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