MULTI-SOURCE CORRELATOR TRACKER WHITE PAPER

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Benefits of MSCT:

- Performs weapons direction and cueing
- Object-oriented design adapts to multiple mission areas
- Combined track management and data correlation capabilities
- Can handle radar plots and track inputs
- Correlates real-time, near-real-time, and non-real-time data
- MSCT's tracker uses Interacting Multiple Model (IMM) filters for handling non-cooperative and high-G targets
- MSCT's tracker was designed to operate on stationary and moving platforms
- Performs three types of automatic sensor registration: relative registration, absolute registration with respect to an ECEF coordinate frame, and registration to an aligned source (e.g., A/C with GPS pods)
- Built-in Link and Force order processing
- Built-in simulation generation capability via Distributed Interactive Simulation (DIS)
- Adapts to wide range of legacy processing and communications configurations

The Quest For A Single Integrated Picture (SIP)

A single integrated picture (SIP) provides US military forces reliable information about ground, air, space, and undersea threats in a theater of operations, including the continental United States.

If a cruise missile fired from a ship or submarine offshore entered U.S. airspace, national authorities would detect it but would not know its origin. Such a scenario was presented at a summer 2001 counter-terrorism exercise conducted by the North American Air Defense Command (NORAD). One situation in the exercise, called Amalgam Virgo '01, consisted of firing of a cruise missile from a nondescript merchant ship in the Gulf of Mexico into the U.S. mainland. Because cruise missiles fly at low altitudes, NORAD would not be able to see them from beyond the horizon.

The cruise missile threat is one of many vulnerabilities that could be solved if the Defense Department and the military services had a real-time SIP of any given battle zone. This conclusion was reached in a study titled "Roadmap to the Single Integrated Picture." [1]

The SIP Solution: The Multi Source Correlator Tracker

MSCT is a highly sophisticated collection of object-oriented, performance-based, software components written in ANSI C++ that implements a field-tested and proven correlation and tracking capability. MSCT performs contact-to-track and track-to-track correlation and fusion of real-time local and remote data. When combined with Raytheon Solipsys' Tactical Display Framework (TDF), MSCT provides a complete solution to the multitarget-multisensor data fusion and SIP problem. Independent Government personnel, research and development laboratories, and four US Armed Services have verified MSCT's capabilities and configurations through numerous tests and field events.

MSCT is a mature collection of statistically-based algorithms and heuristics that provide disparate source correlation and data fusion at the radar plot level and at the track level. MSCT has been under development for over ten years and has a heritage tracing back to the Advanced AEGIS Correlator/Tracker (AACT).

MSCT supports all of the tactical data feeds and formats (TDL-A, TDL-B, and TDL-J), and includes many radar interfaces.

Different configurations allow MSCT to operate laterally or hierarchically. MSCT was designed to correlate data from multiple source track databases. Therefore, tracks from one set of sensors and data sources can be correlated and fused using MSCT. This yields one composite track database. Tracks from another set of

1 Sandra I. Erwin, "Lack of 'Single Integrated Picture' Hinders Commanders, Study Says," National-Defense Magazine, November 2001

sensors and data sources can be correlated using a second MSCT to yield another composite track database. Moreover, tracks can be exchanged laterally between these two MSCTs. The composite track databases produced by these two MSCTs can be correlated and fused using a higher-level MSCT by treating each of the composite track databases as source track database.

An extension to more than two source track databases is straightforward. MSCT provides manual tracking, semi-automatic tracking, automatic tracking, correlation, and fusion functions. Its libraries contain a rich collection of registration and verification techniques to ensure that data from multiple sources is aligned in a common coordinate frame. MSCT can be configured in numerous ways and it provides an extensive set of user-adjustable parameters that control the way it performs.

MSCT History

MSCT was developed by former engineers from the Johns Hopkins University Applied Physics Laboratory (JHU/APL) in 1997 to fuse real-time surface ship and aircraft data from disparate sensors and systems for situational awareness and ID management. MSCT was first deployed as part of the All Services Combat Identification Evaluation Team (ASCIET) 1997 exercise in support of the USMC.

At the time, there were no open architecture commercial-off-the-shelf (COTS) correlator/trackers on the market that could handle the demanding needs of constructing and disseminating an accurate air and surface picture to multiple nodes. Most systems operated at much lower data transfer rates and did not have the sophisticated mathematics and software infrastructures required to meet the full spectrum of performance requirements (weapons cueing, close control, etc.) MSCT also provided a much needed bridge between emerging real-time systems such as the Cooperative Engagement Capability (CEC) and Aegis Weapons System (AWS) and the well-established near-real-time Joint Maritime Command Information System (JMCIS).

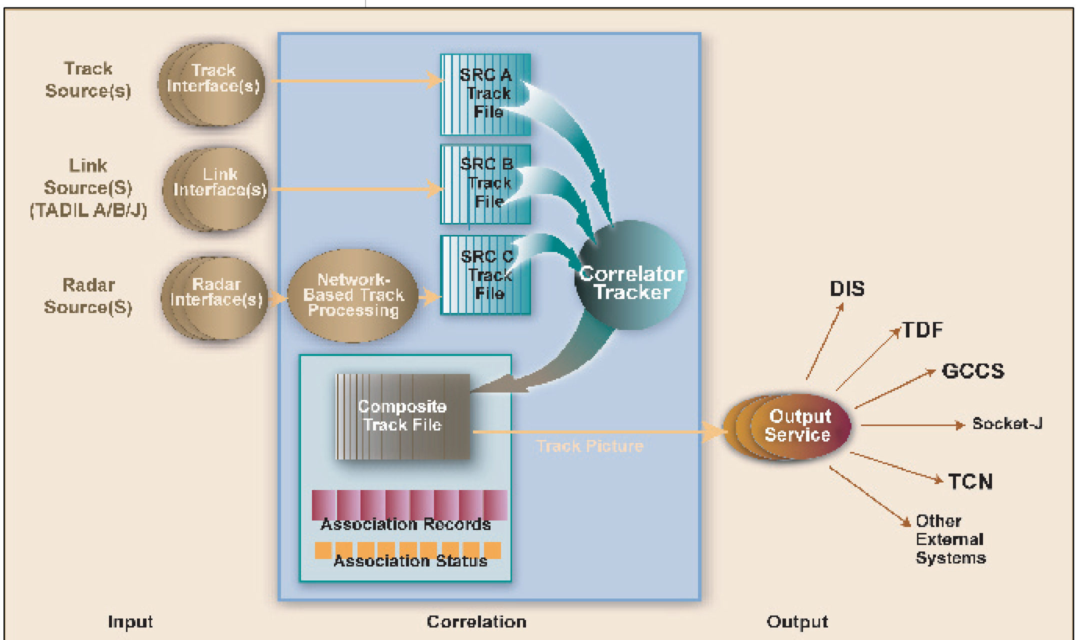
MSCT was the first to market with the required capabilities and quickly gained a following within the community. The product has been rigorously validated by independent government laboratories and industry organizations.

MSCT Technical Overview

MSCT is comprised of a collection of independently configured, cooperating software processes written in ANSI C++ that collectively produce a Single Integrated Picture (SIP). All programs are executed via command lines embedded in a shell script. The system is currently compiled using the GNU g++ compiler and is supported on the Sun Sparc and the x86 architectures under the Sun Solaris operating system (Version 8-10) and RedHat Linux ES 3 & 4 respectively. MSCT has been designed with rapid prototyping and spiral development in mind. Its sophisticated and mature component architecture provides the ability to extend internal features and modify nearly all aspects of the product.

Architecture

MSCT is an integrated collection of modules that perform message translation, tracking, correlation, fusion, and registration. The three-tiered, object-oriented component architecture of MSCT is a key ingredient to its success. The first tier, the left most portion of the diagram, consists of independent and parallel input processes that adapt to the unique protocols and message formats of the systems to which they are interfacing. For example, one input process may be created to handle raw plot data in Asterix format whereas another input process will interpret OTH-Gold track data. Both input processes operate in parallel and essentially perform the same high-level functions but they are completely independent and tailored to the connected system. The input tier is also responsible for converting legacy and proprietary data formats into a generalized internal form that simplifies processing within MSCT. This architecture allows for the rapid integration of new radar message formats and track message formats. It also leads to a more robust and reliable system since only the new interface needs to be validated when a new sensor or set of track messages is added to the system. The second tier of the MSCT architecture is devoted to the creation of the SIP from the various inputs. This tier relies on a series of reusable class libraries such as SoliNet, SoliMath, and Solipsys Library for Automated Tracking and Estimation (SLATE) to optimally combine all of the external sensor and system data.



SoliNet provides MSCT with classes for common tasks such as time synchronization, event/message logging, configuration file and command line processing, and data extraction. SoliMath provides data structures for measurements and track states. Solimath also provides methods for standard mathematical routines such as coordinate transformations, filtering, and state estimation. Slate performs multi-radar multi-target tracking, correlation, fusion, and registration and represents the core of the MSCT plot-processing system.

The third tier of the MSCT architecture is the output tier. It mirrors the functionality encountered in the input tier but in a reverse direction. At this stage, all raw data has been processed and combined into a composite track database and the information in the composite track database can be distributed to other systems and displays. MSCT has a process called TDF Display Server which communicates with the TDF visualization software. Other output processes are available in MSCT to convert the composite track database into a format that can be recognized by other systems downstream. Interfaces can be added to MSCT's output tier with minimal effort to disseminate data in a prescribed customer-defined format.

Interface Capabilities

MSCT is comprised of many independent processes, programs, and interfaces. It can change from customer to customer depending on the required capabilities.

MSCT has been in production since 1997 and regularly participates in inter-service and multi-national simulation and field events, and has amassed a large number of supported system interfaces, software protocols, and data formats. A sampling of the most commonly requested interface types and formats are discussed in the following table and the sidebar.

Interfaces/Systems Supported

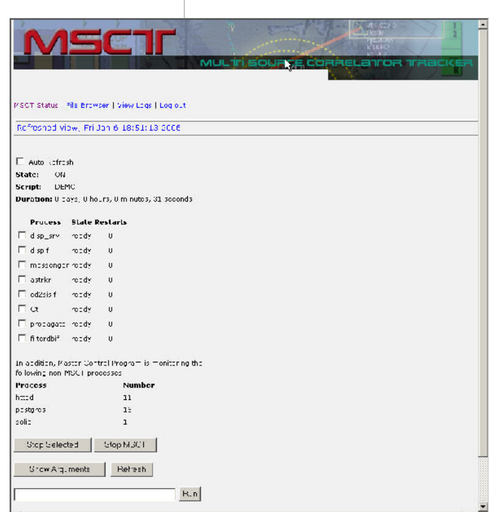
Global Command and Control System (GCCS)	Tactical Data Link (TDL) and Data Link Routers (ADSI, MTDS, IMTDS MSCS)
Joint Range Extension (JRE)	Joint Tactical Information Distribution System (JTIDS)
National Marine Electronics Association (NMEA) GPS	Flight Explorer
Distributed Interactive Simulation (DIS)	Joint Range Extension Application Protocol (JREAP)
Display data interface for trace data	Sensis SIU, and many others

Each sensor interface is developed according to a single radar specification. The sensor interface processes data independent of each other and is configured to transmit data to an internal tracking and fusion engine (SLATE) for further processing. Track interfaces are configured to store data directly into shared memory. Both types are stored sequentially and prepared for correlation with other tracks.

Some customers use a Solipsys-designed and controlled program interface called the Generic Message Interface. This interface enables the input of both raw plots and track data. Since Solipsys controls the interface, the company can provide customized messages and an Interface Control Document (ICD). Customers can develop their own program to interface with MSCT. Solipsys always maintains backwards compatibility with earlier versions of the Generic Message Interfaces.

SLATE

MSCT consists of a sensor measurement processing capability [i.e., Solipsys' Library of Automatic Tracking & Estimation (SLATE)] and a track processing capability. Tracks that are formed from plot-only data originating from one or more sensors are stored in one database. Tracks that are received over links (e.g., TDL-A, TDL-B, TDL-J, Sentinel, etc.) are stored in other track databases on a source-by-source basis. The entire set of



Radar Types Supported

All ARSR radar types (ARSR-1D, 1E, 2, 3, 4, etc.)

All ASR radar types (ASR-7, 8, 9, etc.)

Many AN/TPS types (AN/TPS-59, AN/TPS-63, AN/TPS-75, AN/TPS-43, etc.)

AN/FPS-66, AN/FPS-67,

AN/FPS-20, AN/FPS-117, etc.

AN/MPQ-64 (Sentinel)

AN/TYQ-82

AN/FYQ-9

Data Formats Supported

CD2/CD2A

ASTERIX

DTE

OTH-Gold

TDL-A, TDL-B, TDL-J

- **Flexible** - MSCT is flexible to new configurations, both in reconfiguring for new inputs in the field,and adding support for new data formats quickly with little impact to pre-existing capability.

- **Extensible** - Acknowledging that military modernization occurs over longer periods of time and that legacy systems are inherently less flexible than modern systems, Raytheon Solipsys engineers purposefully designed MSCT from the ground-up for extensibility and adaption.

- **Portable** - MSCT is portable in two ways; from various hardware architectures, having successfully run the same code on SUN Sparc hardware, Intel compatible hardware running RedHat Linux, and Solaris x86 and portable from a physical perspective as well, running on systems as small as a laptop with proper configuration, and as large as both Sun Sparc and Intel hardware.

- **Outstanding Performance** - MSCT has great performance numbers. During the test at SEADS/NSSF in which~120 RADAR feeds were fed into the MSCT on the SunFire 4800, it widely discussed that we were seeing "a first", meaning that no system up to that point had been able to handle so many simultaneous data feeds. It was also pointed out that our system still had room to add more data feeds. 84th RADES ran out of capability to input more.

- **Reliable** – Unlike other correlation systems on the market, MSCT is designed for unattended 24/7 use in mission-critical situations, where system failure is not an option. It has operated for months at a time without fault in war-time situations and in homeland defense applications. The product is very mature and stable and undergoes rigorous internal testing prior to every release.

track databases are correlated and combined to form the composite tracks.

SLATE is the culmination of decades of combined real-world tracking experience from Solipsys' principal staff. This real-world experience is complemented by modern algorithms provided by Solipsys' research and development staff. SLATE encompasses both single sensor and multi-sensor components.

SLATE is an object oriented ANSI C++ library allowing decoupling of complex sub-components. It has a simple API that allows rapid development of new "wrappers." The result is a generalized tracking and estimation library which is highly configurable.

Data Storage

Numerous shared memory and disk-based relational databases are accessed, maintained, and updated by MSCT at a rate closely tied to the input data stream. For instance, raw plot data flows into the system at a high rate and is somewhat transient, so a shared memory segment is utilized for storage. On the other hand, flight plan data is updated much less frequently and is more transactional in nature, so a relational database product such as postgres is used.

Graphical User Interface (GUI)

The MSCT GUI consolidates common MSCT management operations into a single graphical interface. The GUI currently provides mechanisms for MSCT operators to start, stop, and edit MSCT scripts and to monitor and modify the state of a running MSCT. The MSCT GUI was written to provide the customer a way to control MSCT without the VI editor and UNIX commands.

The GUI is hosted by an Apache web server on the same machine as MSCT. A script called cgiwrap is used to run the GUI scripts as the appropriate user. CGI scripts on the server generate all of the GUI pages. These pages are nearly pure HTML to allow all web browsers to properly display them. Some newer features of the GUI (for example, automatic refresh of status pages) take advantage of javascript and other techniques which require a native web browser, such as Microsoft Internet Explorer or Mozilla Firefox.

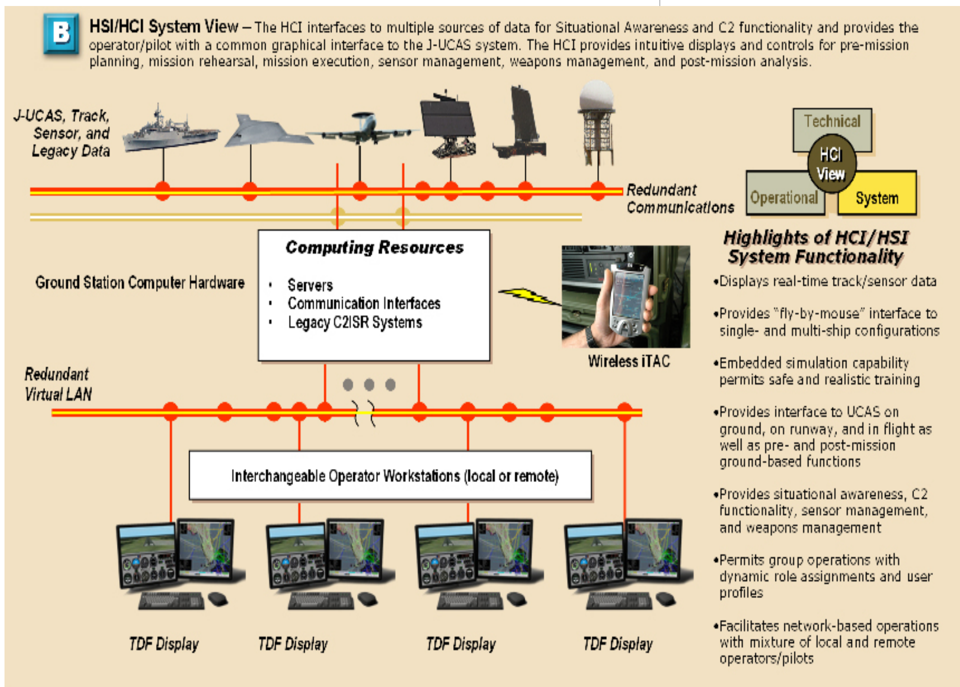
The CGI scripts are perl scripts that wrap MSCT and UNIX commands, translate browser input into command line input, and translate command line output to HTML. This separation leaves most of the actual administration functionality inside MSCT to help synchronize MSCT user interface features (whether command line or GUI).

The GUI uses a password-based authentication system that supports multiple users. Currently, any authenticated users have full access to the MSCT user interface. However, there is the possibility of creating multiple levels of access in the future.

System Integration

The MSCT can be integrated with third party systems via interfaces based on two-way communications. The mode of transport for the connection is typically determined by what the external system supports. Most of the MSCT interfaces support both TCP (either server or client) and UDP connections. Some support both forms of TCP as well as serial connections.

The standards supported by the MSCT include TDL-J, TDL-B, GCCS-M, GBDL(E), FDL, RRDL, and TCG's LinkPro Transactions. The most commonly used standard is TDL-J, although external systems differ greatly in the chosen mode of transport. In order to support all of the different transports without maintaining multiple versions of the interface, a program has been developed to support UDP, TCP server, TCP client, and serial connections to TDL-J systems. It also supports several different header standards, including JRE, LSE, MTC, and Exlan. The mode of transport and header is specified per interface instance at the command line. This method of multiple I/O transport support within a single interface is the intended solution for most MSCT interfaces in the future.



Customer Applications

MSCT is a COTS product and has been used for air surveillance and defense for nearly ten years in the United States, Australia, South Korea, and Italy. It has played a major role in many military exercises and field tests since 1997.

Summary

MSCT is a proven and flexible correlation and tracking capability used by operators and system developers around the globe. It meets the rigorous accuracy and timing requirements of mission-critical applications and acts as the data fusion engine for numerous systems of record, including those described in this white paper and a variety of other applications. By leveraging its component-based architecture, new interfaces can be quickly developed and deployed to meet emerging requirements.