SLID FIRE CONTROL SYSTEM
INTEGRATED SENSOR SUITE

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Abstract

Rockwell International Corporation has been developing a small, autonomous, active self defense system over the past four years under IR&D and government contract. One element of this system is a fully integrated fire control system that, in a small package, contains a full sensor suite for threat warning, tracking, and designation of threat missiles and projectiles and intercepts at standoff ranges of 100 to 300 meters. Axial propulsion is provided by a short-burn rocket motor which boosts the interceptor to a velocity of 260 meters/second.

The most stressing SLID system requirement is defense of a protected vehicle from a High Explosive Anti-Tank (HEAT) round fired from a range of one kilometer. The SLID TWS senses the muzzle flash at t=0 and takes 50 millisecond to extract the flash from the background, run it through the FCS processor, declare it as a potential threat, and hand over the global coordinates to the tracking system. The FCS tracking turret and optical pointing system take another 150 milliseconds to rotate to the defined coordinates, put the narrow field of view infrared tracking sensor's acquisition gate on the incoming round, process the image, lock the tracking gate down, and activate the co-bore sighted laser. In another 50 milliseconds the FCS laser receiver and processor determine the threat kinematics in 3-dimensional space, define the optimum intercept point for 100 meter standoff at intercept, and pass those coordinates to the launcher. The launcher slew and settles in another 250 milliseconds while the thermal batteries on board the interceptor are activated. Tracking functions are then handed over from the narrow-field-of-view infrared tracker to the laser designator/autotracker system. The laser prf switches from 100 Hz to 750 Hz and the interceptor is launched through the frangible cover of the launch tube. Four hundred milliseconds later the HEAT round is struck in flight and destroyed. Total elapsed time is 9/10ths of a second from launch flash to intercept.
SLID System Overview

The SLID active defense system consists of four major elements which are integrated to perform the SLID mission autonomously and efficiently. These are the TWS, the FCS, the high slew rate launcher, and the hit-to-kill interceptor. These systems are supported by an external power supply which converts and distributes 28VDC input power and contains capacitor banks for surge power requirements when the launcher is activated and responding to pointing commands. All system signal processing (except for interceptor guidance and control) is done with the FCS central processor, a C-80 based system which has adequate speed and throughput for all of the system's processing requirements. The subsystems that make up the major system elements are shown in Table I, and a chronological summary describing the SLID operational concept is shown in Figure 2.

Table I. SLID Subsystems

<table>
<thead>
<tr>
<th>System</th>
<th>Subsystem</th>
<th>Description</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>TWS</td>
<td>Threat Warning</td>
<td>WFOV MWIR Camera</td>
<td>640x480 MCT (4 ea.)</td>
</tr>
<tr>
<td></td>
<td>(see note 1)</td>
<td>or WFOV LWIR Camera</td>
<td></td>
</tr>
<tr>
<td>FCS</td>
<td>Fine Tracking</td>
<td>NFOV MWIR Camera</td>
<td>640x480 MCT (1 ea.)</td>
</tr>
<tr>
<td></td>
<td>(see note 2)</td>
<td>(see note 3)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rangefinding,</td>
<td>Laser/Laser Receiver</td>
<td>1.06 micron NdYag</td>
</tr>
</tbody>
</table>
Table 1. SLID Subsystems (continued)

<table>
<thead>
<tr>
<th>System</th>
<th>Subsystem</th>
<th>Description</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Designating and</td>
<td>Processing</td>
<td>System Central</td>
<td>C-80 based</td>
</tr>
<tr>
<td>Terminal Tracking</td>
<td>Processor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Launcher</td>
<td>Precision Pointing</td>
<td>DC Torquer motors</td>
<td>Direct Drive</td>
</tr>
<tr>
<td>System</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interceptor</td>
<td>Seeker</td>
<td>Strapdown Laser</td>
<td>128x128 InGaAs Detector</td>
</tr>
<tr>
<td>Guidance</td>
<td>Solid Diveters</td>
<td>150 lbf x 5ms</td>
<td>(72 ea.)</td>
</tr>
<tr>
<td>Propulsion</td>
<td>Solid Rocket</td>
<td>3000 lbf x 80ms</td>
<td></td>
</tr>
</tbody>
</table>

Notes
1. MWIR threat warning subsystem for lower 30 degree coverage; LWIR threat warning subsystem for upper 60 degree coverage.
2. WFOV=Wide Field of View; NFOV=Narrow Field of View
3. MWIR=Mid Wave Infrared; LWIR=Long Wave Infrared
4. MCT=Mercury Cadmium Telluride

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**Figure 2. SLID Operational Concept**

- **Event**
  - Detect Threat Signature
    - Airframe Signal Increase With Closing Range
  - Acquire and Track Threat
  - Rangefind / Designate Threat
  - Slew Launcher and Fire Projectile
  - Guide to Hit-to-Kill Intercept

- **Key Subsystem**
  - IR Threat Warning Sensor
  - IR Tracker
  - Laser Rangefinder / Designator
  - Launcher
  - Interceptor

- **Action**
  - Surveillance Over 360°
  - Frame to Frame Registration
  - Cue Tracker
  - Slew Mirror ±180° @ 600° / sec
  - Acquire Threat
  - Track 0.14 mrad @ 120 Hz
  - Catalog Threat Trajectory
  - Cue Laser Rangefinder
  - Illuminate Target
  - Rangefind 120 MJ @ 100 Hz
  - Catalog Threat Velocity & TOA
  - Slew Launcher ±90° @ 450° / sec
  - Squib Projectile Battery
  - Delay Ignition Until Threat Within Firing Range
  - Launch at 260 m/sec
  - Designate 38 MJ @ 750 Hz
  - Flyout to Standoff Range
  - Guide to <2 in. CEP Intercept
**SLID Fire Control System Description**

The TWS performs the threat detection function. It consists of either four WFOV MWIR sensors for line-of-sight threats such as HEAT rounds or anti-tank guided missiles, or four WFOV LWIR sensors for top-attack threats such as mortar and artillery rounds fired from deep defilade. Figure 3 shows the TWS sensors attached to the side of the FCS housing. In operation, the TWS detects the engagement event and then cues the tracker to the threat coordinates. These threat coordinates are input into the system processor threat table, and while the tracking optics are trained on the potential threat, the TWS continues to stare at the environment. Should another engagement event (e.g., launch flash) be sensed, the coordinates of that event would also be input into the threat table for interrogation a few milliseconds later. Fire control functions are then handed over to the tracker/designator subsystem.

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**Direct Fire TWS**
- For Horizontal Attack Threats
- Lower 30° x 360° Coverage
- Four WFOV MWIR Sensors
- Excellent Performance Against Clutter Background

**Top Attack TWS**
- For Mortar and Artillery Threats
- Upper 60° X 360° Coverage
- Four WFOV LWIR Sensors
- Excellent Performance Against Cold Targets

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![Figure 3. SLID Threat Warning Sensors](image-url)

The tracker/designator subsystem uses a 3-degree field-of-view MWIR camera for fine tracking, and contains a co-bore sighted 1.06 micron NdYag laser and laser receiver. The laser and laser receiver provide ranging finding, designating, and autotracking functions. Following handover from the TWS, the tracker/designator interrogates each of the candidate threats in the threat table to determine validity and priority. Non-threats are removed from the threat table, and priority threats are engaged before secondary (slower moving) threats. For threat interrogation the laser operates in the rangefinder mode with a prf of 100 Hz, an output energy of 120 millijoules, and a conical beamwidth of 1 milliradian. Beam steering is conducted with two stabilized steering mirrors in the optical dome as shown in figure 4, which is an exploded view of the tracker/designator subsystem elements. The dome features continuous 360 degree rotation for coarse tracker alignment, and all drive motors are sized for near instantaneous response.

Once the system commits to launch an interceptor, the laser is switched from rangefinding to the designation/autotrack mode of operation. The laser prf is increased to 750 Hz (required by the SLID interceptor for terminal accuracy), output energy drops to 38 millijoules (a consequence of the prf increase), and the beamwidth is increased to 4 milliradians to assure that the threat remains within the beam during autotrack. Prior to launch of the interceptor, the tracking functions are transferred from the IR tracking system to the laser receiver (required due to flash-blinding of the IR tracking sensor by the interceptor's rocket motor). Once autotrack is operating, the interceptor is launched, homes on the threat via reflected laser energy, and destroys it at the prescribed standoff distance.
SLID FCS Performance

The FCS subsystems that perform the cueing, tracking, and designating functions have been selected based on studies and tests which have confirmed their performance in both good and inclement weather, and under the influence of dust, smoke, and other battlefield obscurants. These evaluations have demonstrated the robustness of the selected technologies for SLID application and have provided useful information for systems analyses of the performance timelines against a full range of surrogate threats, including HEAT, mortar, and artillery projectiles, and TOW, Dragon, and HELLFIRE missiles. Additionally, field testing has been conducted over the past two years to evaluate both wide and narrow field of view MWIR and LWIR sensor performance in clear, cloudy, hazy and overcast weather against Dragon and TOW missiles, and against HEAT and mortar projectiles. The laser designator and autotracker system have been evaluated in field tests against TOW missiles at Redstone Arsenal, Alabama where designation and tracking functions were demonstrated at a range of 850 meters using a low energy (5 millijoule) laboratory laser. Additionally, laser attenuation in the presence of rocket motor plume effects has been evaluated during rocket motor static firing, and attenuation values of less than 50 percent (maximum, worst case relational geometry) were demonstrated.

Figures 5 through 8 show predicted clear weather performance of the threat warning, tracking, and designating systems against a large subset of the surrogate threat list. Performance of both WFOV MWIR and WFOV LWIR threat warning sensors against 81mm mortars is currently under evaluation.
Figure 5. Threat Warning Sensor Performance against Threat Launch Flashes

Figure 6. Threat Warning Sensor Performance against Threat Airframe with Aerodynamic Heating
Conclusions

Almost all of the SLID FCS technologies have been demonstrated in real-time field evaluations against a large subset of the surrogate threats, and prototype hardware is currently being designed and fabricated for end-to-end field tests against live targets in mid 1998. Test objectives include intercepts of TOW and mortar threats at ranges in excess of 100 meters, and the successful conclusion of this test series will signal readiness for full scale development, production, and fielding of SLID systems for protection of allied troops and assets on future battlefields.
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