TRACER DETECTION TECHNOLOGY CORP.
PRODUCTS AND SERVICES FOR CORPORATE AND GOVERNMENT SECURITY

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FINAL REPORT

Grant # 2001-LT-BX-K005
(Grant Period: 8/01/01 to 1/31/02)

"IDENTIFICATION AND TESTING OF AVAILABLE SENSORS FOR THE DETECTION OF PERFLUOROCARBON"

"Supported under Award Number (#2001-LT-BX-K005) from the Office of Justice Programs, National Institute of Justice, Department of Justice. Points of view in this document are those of the author(s) and do not necessarily represent the official position of the U.S. Department of Justice."

OVERVIEW

In August 2001, Tracer Detection Technology Corp. (Tracer) was awarded a contract from the National Institute of Justice (#2001-LT-BX-K005) for the purpose of advancing the Chemical Tagging program toward field utilization by identifying an available, cost-effective method of detection. Work under this contract was conducted at the New York State Center for Advanced Technology in Diagnostic Tools & Sensor Systems (the "Sensor CAT") at the State University of New York at Stony Brook (SUNY). Tracer and SUNY are referred to herein as the Project Team

The overall objectives of this effort were to:

- Survey, acquire for testing and evaluate currently available detection technologies and sensors from both the government and commercial sectors to permit future work on application specific PFT-"taggant" formulations and companion detection methods. This work was conducted with a PFT taggant similar to that was used in a previous demonstration (February 2000).

- Present results and indicated actions to a meeting of a Law Enforcement Advisory Panel to be convened by the National Institute of Justice.

The following provides Tracer's Final Report for Grant # 2001-LT-BX-K005 (Grant Period: 8/01/01 to 3/30/02), "Identification and Testing of Available Sensors for the Detection of Perfluorocarbon."

Appended hereto is the Technical Report provided by the New York State Center for Advanced Technology in Diagnostic Tools & Sensor Systems (the "Sensor CAT") at State University of New York at Stony Brook with Tracer Detection Technology Corp. A reconciliation of the budget is also provided.

BACKGROUND:

Perfluorocarbon tracers (PFT) are safe, volatile, non-reactive, environmentally benign compounds. The ambient background concentrations of the five routinely used PFTs are in the range of parts per 10^{15} of air. The perfluorocarbon tracer technology, by virtue of its high vapor pressure provides the unique ability to permeate closed doors and windows, containers and luggage, yet is impervious to electronic interference and other problems inherent with tagging technologies. Once a location reaches steady state, an actively emitting tagged item should provide vapor traces that are detectable in the vicinity of the item (even temporarily following removal of the tagged item). It is noted that an issue has been raised regarding the global warming potential of the Perfluorocarbon class of compounds. A detailed paper and discussion this subject follows in a separate section of this report. It is important to note however, as stated, these materials have ambient background concentrations of the five routinely used PFTs are in the range of parts per 10^{15} of air. This fact not only makes PFTs ideal candidates for tagging and tracking, but also for their principal, non-medical use in environmental testing, environmental testing, and also forms the basis of their extremely low global warming impact. Brookhaven National Laboratory routinely uses PFTs in its work for the Environmental Protection Agency, National Oceanic & Atmospheric Administration (NOAA) and various public utilities.

In June 1999, Tracer was awarded a grant from the National Institute of Justice (#1999-LT-VX-K008) for the purpose of conducting a demonstration of the use of an encapsulated Perfluorocarbon tracer taggant with the work being performed at Oak Ridge National Laboratory. The objective of this demonstration was to mark and then identify the existence and location of a "tagged" (or marked) source. This demonstration was conducted at Oak Ridge National Laboratory on February 14 and 15, 2000 (Final Report to be submitted in June, 2000). The demonstration was attended by Tracer Detection Technology Corp., the National Security Program Office at ORNL and representatives from the City of Knoxville Police Department, the National Institute of Justice, the National Law Enforcement Technology Commercialization Center, the Department of Defense CounterDrug Technology Development Office, F.B.I., and a representative of one of the National Security agencies.

Indicated Actions of Grant # 1999-LT-VX-K008

One of the overall conclusions of this grant program was that depending on the application scenario, there might be a number of short and longer-term detection technologies available (or to be developed), and that rather than developing a new sensor for the detection of Perfluorocarbon, it was considered more prudent to determine the appropriateness of additional, available detection technologies for these applications. These alternatives were:

a. Contact, close proximity, choke-point: A DSITMS or a gas chromatograph with an electron capture detector (GC/ECD) are now available for close range detection. It is assumed that certain sensors that are currently available either commercially or within the law enforcement arsenal that might be capable of selectively detecting the PFT taggant. Specifically:

- a portable version of a GC/ECD
- use of an Ion Mobility Mass Spectrometer
- others to be identified

b. Non-Realtime Detection: Field sample collection with delayed laboratory analysis scenarios and field tests was discussed. This would involve the placement of absorbent capture sampling tubes at the site of suspected illegal activity, and the subsequent collection and analysis of the sampling tubes to confirm that a "tagged" source has been in that area.

All detection for this demonstration was done in real time.

CURRENT PROJECT GOALS (#2001-LT-BX-K005)

Recognizing the potential utility of the Perfluorocarbon tagging method for tracking and identification of illicit goods and activities in law enforcement and national security, the purpose of this program was to offer the law enforcement community with an affordable, off the shelf detector/sensor system for the detection of the Perfluorocarbon taggant developed under the previously funded program with the National Institute of Justice.

The primary goal of this effort will be to identify one or more commercially available detectors or sensors that with minimum re-engineering, can be demonstrated to detect the Perfluorocarbon taggant at similar levels of sensitivity to the Direct Sampling Ion Trap Mass Spectrometer that was employed in Tracer's demonstration in 2000.

WORKPLAN

Initially, Tracer surveyed the commercial and government arenas, and identified prospective sensor and detection schemes that might be amenable to the detection of the Perfluorocarbon taggant. Arrangements were made to purchase, lease or acquire on-loan these devices for subsequent testing and evaluation at the Sensor CAT. These prospective devices were then evaluated by the Sensor CAT to determine their sensitivity to the Perfluorocarbon taggant, and the inherent range of detection. The benchmark for this testing was a comparison to the work and findings previously determined by the scientists at Oak Ridge National Laboratory. Testing was conducted using taggant samples similar to those used during Tracer's earlier demonstration program at ORNL.

OVERALL CONCLUSIONS

The objective of this collaborative effort of Tracer Detection Technology Corp. (Tracer) and the New York State Center for Advanced Technology in Sensor Systems of State University of New York at Stony Brook (Sensor CAT) was testing the potential of commercial sensing technologies for detecting small concentrations of the tracer compound perfluoro-1,3-dimethylcyclohexane (PFT). Two different detection technologies were successfully tested in the course of this project (gas chromatography and adsorption samplers). Two others, were not evaluated in detail at this juncture (for budgetary reasons) in demonstrating their ability to detect the Perfluorocarbon tracers, but did show promise and suggest additional investigation and testing. One, FTIR detection, was extensively investigated theoretically. The other, a combination of IR illumination and sensor was also investigated, and holds great promise once the device is modified for PFT detection.

The results further confirmed the potential of PFT taggants for law enforcement purposes. The portable gas chromatograph (GC) with an electron capture detector, manufactured and provided by Sentex Technology, Inc., was shown capable of effective PFT detection. The passive CATS samplers have also demonstrated good performance in tracing small concentrations of PFT vapors. FTIR detection deemed to be very promising, after some additional research on PFT absorption spectra and development to substantially increase the equipment sensitivity; we have outlined the directions of such research and development. Illuminators and detectors exist potentially capable for active far-IR spectroscopic detection of PFT; further research is needed to evaluate this method's prospects for law enforcement purposes.

The tagging for experiments was done by paraffin (wax) crayons filled with PFT, as in earlier ORNL experiments. Passive miniature PFT samplers were provided for testing by BNL-AIMS (a paper describing the Air Infiltration Measurement System is attached).

SUMMARY OF THE RESULTS

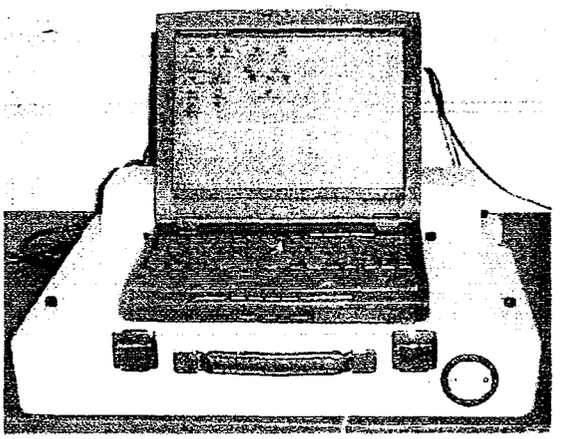
A series of tests and experiments were conducted, with the intent of duplicating, at lease in part, the scenarios that were performed at Oak Ridge National Laboratory under the previous grant from the N.I.J. Simply, these were to be able to detect small amounts of the PFT taggant in a room and to simulate the tagging of currency that might be used in an illegal operation. It should be remembered that this was a sensor evaluation, and therefore no effort was made to improve the formulation or persistence of the chemical taggants used.

PFT DETECTION WITH GAS CHROMATOGRAPH

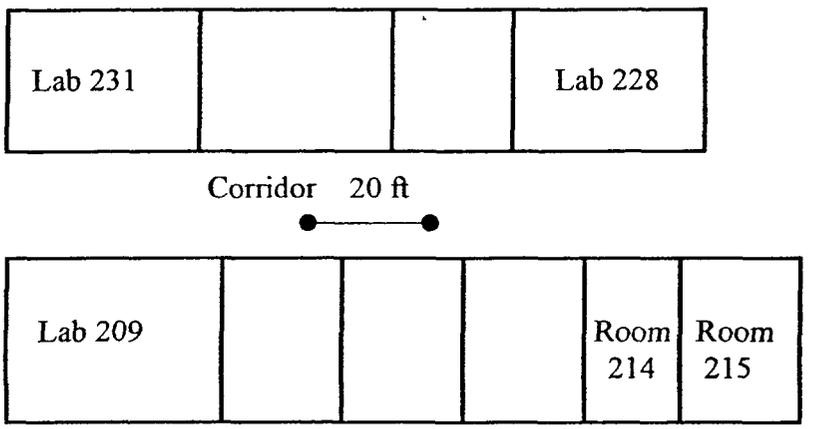
The device

Portable chromatograph manufactured by Sentex

The portable (20.5x19x7 in^3) version of GC, Fig. 5, is equipped with a battery and can be powered by a supply line or be self-contained for at least 3 hours. The control laptop keeps the GC parameters at the pre-setting levels, performs calibration and analysis of air samples captured in a loop (a piece of a plastic tube), and displays the signals on a screen. Carrier gas (helium) pressure in a chromatographic column was kept at a level of 15 psi.



The device was tested on the Sensor CAT premises (SUNY at Stony Brook, Old Chemistry Building, second floor). Background concentration of PFT vapors was measured both inside and outside the building. Tests with the paraffin crayons filled with liquid PFT and PFT vaporized inside the building were performed as well. The preliminary test and the final test in the presence of Tracer president Mr. Jay Fraser were videotaped. The tests were performed in three laboratory rooms of the Old Chemistry Building at SUNY at Stony Brook: # 209, 228, 231. Tests with PFT tracing were carried out in the rooms 209 and 228; room 231 was kept clean of PFT for background reference measurements. The layout of the premises is shown directly below.



Floor map of the Sensor CAT Premises ON THE 2nd FLOOR OF THE OLD CHEMISTRY BUILDING USED FOR PFT TESTS

Preliminary test

The test allowed us to experimentally verify and quantify the PFT dynamics in our specific conditions. It also demonstrated the device capability to work, if needed, even with the high self-generated signal. The detectable concentrations under such circumstances, however, would be, while realistic, quite high.

Stage 1: ***Investigating the dynamics of PFT concentration in the room.***

Background signal (mostly self-generated, however referred as background signal further on) in the room 209 was 59 ppb. A stack of paper pieces imitating money bills was tagged with PFT by "swiping" the paraffin crayons filled with PFT (~ 10% of liquid PFT by volume) and placed on a shelf in a cabinet located in the room 209. The test was performed to determine PFT concentration rise and decreasing in the room (3500 cubic feet).

TABLE 1

Time after tagging (min)	Count, ppb
2	115
15	103
47	421
81	161
160	93

Conclusion from this stage: the time of the concentration build-up in the room was approximately 50 min, and characteristic concentration decay time was ~ 1 hour; it corresponded to the calculated PFT concentration time dependence for ventilated premises with the ventilation rate of 100 cfm.

Stage 2: ***Detecting tagged "money" in an envelope.***

Four standard envelopes were prepared for the next test. One "bill" was put in each envelope, and only one of bills was tagged with PFT by "swiping" a paraffin crayon (~ 20 "swipes").

TABLE 2

Time after tagging (min)	Situation	Count, ppb
1	All four envelopes at the GC input	2490
8	Two envelopes were taken away	45
27	A pair of envelopes tested for previous situation replaced with the envelopes previously taken away	530
32	One envelope taken away, another tested	40
40	The envelope taken away previously tested	60

Conclusion of this stage: the tagged envelope containing only one tagged piece of paper is easily traceable for ~1 hour after tagging. Emission rate decreases (10 times in 20 min) with a characteristic decay time of 5 – 6 minutes.

Stage 3. ***Seeking a room with the tagged stack of "money".*** Preliminary background concentration was measured in the corridor near the rooms 209, 228 and 231b, as well as inside the room 228; corresponding signals were: 43 ppb, 37 ppb, 36 ppb, and 33 ppb. The stack of tagged paper was put in the room 228 into a desk drawer. The search began 1 hour after placing the tagged "money," and proceeded as follows:

- Hall near the room 228: 71 ppb (exceeds background by the factor of two).
- Hall near the room 331b: 36 ppb
- Hall near the room 209: 46 ppb

We concluded: the tagged "money" is in the room 228. 96 min after placing; inside the room 228: 71 ppb, (exceeds background by the factor of 1.9). 104 min after placing; the stack of tagged "money" was removed from the drawer and given the GC to smell (placed under its nose): 670 ppb.

Conclusion: a stack of tagged bills can be traceable during a period of more then 2 hours, moreover a room containing the tagged money can be found by measuring PFT concentration outside the room.

The preliminary test showed that the portable GC could be successfully used in PFT vapor tracing even with a high level of self-generated signal provided that the sufficient amount of taggant (number of paraffin "swipes" containing liquid PFT) is planted in the premises. Besides, it provided necessary experimental data for the calculations of PFT concentration dynamics

4. Final testing

Before the test, GC was working in stand-by mode (column pressure 15 psi, temperature 70 C) continuously for 2 weeks before the test. PFT contamination of the device was reduced significantly, and a self-generated signal (sensitivity) was reduced to 5 ppb.

- Background concentration in the room 209: small, non-measurable
- Background concentration in the room 231: 7.3 ppb
- Background concentration in the room 228: 6.8 ppb

A stack of approximately 60 pieces of paper imitating money bills, each bill tagged with PFT by "swiping" the paraffin crayon, was put in an envelope and sealed. Then the envelope was placed on a desk in the room 228 located approximately at a distance of 2 m from the left (regarding to entrance) wall.

PFT concentration in the room 228 in 15 minutes after placing: 13 ppb, 1 hour 15 min after envelope placing: 131 ppb. The door was closed and nobody entered the room. Another 15 min passed by: 64 ppb. The door was open and people entered and left the room (ventilation through the door was added).

Conclusion of this stage: Concentration of PFT vapors in the sealed room (~ 4000 cft) increased from background level twentyfold (doors closed) in approximately 1 hour. With an open door concentration decreases rapidly, however the level is high enough for detection (10 times higher than the background level).

The GC was transported to the room 209 for the next test.

The envelope containing the stack of tagged bills was given to smell approximately 3 hours after tagging: 28 ppb.

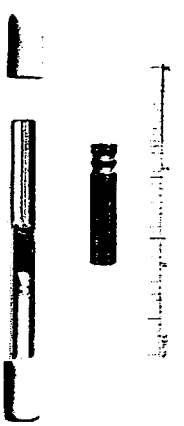
An envelope without tagged bills was given to smell: 19 ppb (this envelope was in the room 228 on the desk in close proximity to the envelope with the tagged bills during the test so that it was apparently cross-contaminated).

A clean envelope from the office was given to smell: 8 ppb.

Conclusion of this stage: the envelope containing a stack of tagged bills can be identified more then 3 hours after tagging.

PASSIVE DETECTION USING THE BNL/AIMS SAMPLING TECHNIQUE

The purpose of this part of the sensor evaluation was to demonstrate the application of the Brookhaven National Laboratory (BNL) Air Infiltration Measurement System (AIMS) to a law enforcement scenario. In the past, BNL has used this technique (described in this white paper: http://www.ecd.bnl.gov/pubs/BNL30797.pdf) to measure air flow within a home or building using controlled emission of PFTs, and passive sampling tubes. The premise was that in a scenario in which a building or location was suspected of being involved in illegal activities, the sampling tubes could be covertly placed by law enforcement. Following a passage of time, these tubes could be retrieved and analyzed to confirm that a source of PFT had entered the environment.



Four passive PFT detectors (CATS – capillary adsorption tube sampler) were provided by the BNL/AIMS for the final test. The samplers are supposed to be used to determine a time averaged indoor tracer concentration with sampling period of two or more hours. The samplers were placed at the following locations:

CATS #1310: in the middle of room 228;
CATS # 157: 1 meter from the wall of room 228 (1m from the desk with the tagged envelope);
CATS #3346: 2 m from the wall of room 209;
CATS #1448: 2 m from the wall of room 231.

Detection start time: 11:45 am; Detection end time: 2:10 pm.

The samplers were sent back to BNL/AIMS after the test for evaluation. According to the data of analysis provided, the following average concentrations were measured:
The results are shown in the table below:

CATS No.	Room	Period (01/02/02)	Air Volume, mL[1]	PDCH[2] Qty, pL	PDCH Conc., ppb
1310	228	1145 – 1355	17.0	147	8.7
157	228	"	"	847	50
3346	209	1210 – 1355	13.7	0.61	0.045[3]
1448	231	"	"	4.85	0.35

[1] CATS sample at 0.131 mL of air per minute
[2] PDCH reported is for the total of all isomers
[3] This PDCH level is about 0.1% of the previous CATS and could be carry-over

The quantity of PDCH found in the 2 standards agreed with the known level in the standard. Further, the levels of PFT were highest in room 228 and quite lower in the other locations.

The averaged value of PFT concentration displayed by CATS #1310 matches the average GC data obtained in room 228. It was shown that PFT concentration was distributed non-uniformly over the room volume and average concentration gradient from the wall of the room where the taggant was located on the desk to the middle of the room is approximately equal to 6 ppb/m.

Conclusion: The detectors demonstrated high performance in PFT detecting, they are small and can be planted discretely in the hidden places of the premises (rooms, buildings, etc.). The apparent complication is, however, that the premises are supposed to be known in advance.

IMPLICATIONS of the DEMONSTRATION

Although there are additional modifications that might make the gas chromatograph less wieldy when deployed in the field, based on the work conducted under this grant, and supported by the successful field activity in Mexico, this method of detection offers the potential to immediately implement operations using the Perfluorocarbon tracer technology for certain applications. At this time, the only limitation on the application would be related to the chemical formulation, the improvement of which was not the subject of this NIJ program.

Additionally, the results of the passive sampling test of this effort revealed strong likelihood that this technique could be effective in confirming the presence of a tagged item within a closed environment.

POTENTIAL FOLLOW-ON WORK

Detection/Sensors

Pending subsequent funding, Tracer Detection Technology Corp. and the Sensor CAT would work with the supplier of the "Illuminator" to adapt it for use in detecting Perfluorocarbon tracers. Additionally, further investigation and testing of the FTIR approach is believed warranted. A discussion of the approach for the remote optical detection of Perfluorocarbon is attached in Appendix I.

Formulations

Improving the longevity of the "taggant" and developing different formulations based on specific applications, weather conditions and other operational considerations are a desired next step. Depending on operational requirements, new chemical taggant formulations to improve longevity could be provided within one year for approximately $250,000. Additional product application enhancements could be developed within the same time frame for approximately $750,000.

MANAGEMENT ACTIVITIES

During the course of this demonstration effort, Tracer Detection Technology Corp.:

- negotiated and finalized a "work for others" agreement with the Research Foundation of the State University of New York under which this demonstration effort was performed.

- worked extensively with the investigators at the Center for Advanced Technology in Diagnostic Tools & Sensor Systems to plan and implement this sensor evaluation program.

- negotiated availability and receipt of sensors/detectors for this program with suppliers.

- worked with a private special operations team, not funded by NIJ, in a kidnapping in Mexico (reports are attached for reference).

OTHER ISSUES

It should also be noted that during the meeting on March 28, 2002 to present the results of this NIJ funded sensor evaluation effort, issues relating to the feasibility of optical detection as well as the appropriateness of the use of Perfluorocarbon as a tracer material from an environmental point of view were raised. The feasibility issue is addressed in two briefs, the first written by Tracer Detection Technology Corp. (Appendix II) and the second provided by the Sensor CAT (Appendix III). A paper written by Dr. Russell Dietz etal. of Brookhaven National Laboratory is attached as Appendix IV. It should be noted that this paper addresses the issue of the global warming potential of the Perfluorocarbon material, and was written in response to questions raised by the U.S. Environmental Protection Agency

PFT TECHNOLOGY

HISTORICAL PERSPECTIVE

In 1993, Tracer Detection Technology Corp. concluded that the PFT technique could form the basis of a unique, highly sensitive and precise tactical tool in the surveillance of illicit drug related activities, and in a range of other law enforcement applications. In November 1993, Tracer presented a paper at the Tactical Technologies and Wide Area Surveillance Symposium in Chicago, Illinois. Subsequently and as follow-up, a number of U.S. Law Enforcement Agencies (LEA) expressed interest in a proposed system to Tag and Detect Drugs, Crops, Chemical Compounds and Currency with Perfluorocarbon. Tracer Detection Technology is the sole licensee of U.S. Patent # 5,409,839 covering a "Method for the Tagging and Detection of Drugs, Crops, Chemical Compounds and Currency with Perfluorocarbon Tracers.

FIELD OPERATIONS EXPERIENCE

In March 1998, Tracer produced and supplied an operational quantity of chemical taggant and a detector in a real-life kidnapping/ransom operation in Mexico City, with the objective of recovering the ransom money. The son of a wealthy newspaper publisher had been kidnapped and had been held for one month prior to the operation in an unknown location. The ransom money was marked with a PFT "tag." Hours later the operations team detected the signal from the PFT tag and later identified the location of the ransom money at three different sites. Mexican authorities arrested all three segments of the kidnapping gang, the ransom money was retrieved and the victim was returned unharmed.

In December 2001, a private special operations team working with the Mexican Anti-Kidnapping Task Force and Counter-terrorism Task Force successfully repeated this activity in the Mexican state of Guanajuato using a gas chromatograph.

Based on the success of these two missions and the pervasiveness of kidnappings in Mexico, it is expected that additional uses of this technology will occur. Further, as these operations have gained the attention of senior Mexican government officials, Tracer expects that an on-going operational capability will be established, specifically for the purpose of retrieving the ransom money and aiding in the apprehension of the kidnappers.

After action field reports for both operations are attached (Appendix V). It should be noted that these represent the unedited observations of the team leader. In some instances, conclusions are drawn that have not been scientifically demonstrated.

Remote Optical PFT Tracing
Executive Summary

1. Overview

The feasibility of passive PFT sensing for law enforcement purposes, proposed by Tracer Detection Technologies, has been successfully demonstrated through a cooperative effort of Tracer and the Sensor CAT. In particular, the gas chromatographer manufactured by Sentex has shown good performance in tracing PFT-tagged objects. At the same, a clear need exists for a sensing technology capable of discovering PFT-tagged objects from a larger distance. Such a technology would be substantially advantageous for law enforcement, especially if it could identify PFT-tagged substances for a distance of several hundred, or even thousand, feet. We ***propose*** to investigate using for this purpose ***active optical excitation*** of the vaporized taggant molecules ***with the remote light source*** emitting light beyond the visual spectrum and ***to observe the fluorescent light*** radiated by the molecules as the result of optical de-excitation. The crux of the problem is to design a system that can be powerful enough to generate the fluorescence with intensity exceeding thermal infrared noise emitted by surrounding objects, including the air itself, and to deploy or develop the detector sensitive enough to allow for reconstructing the "image" of the PFT vapor plume and the location of its source.

2. Spectral Range

There are two spectral regions beyond the visible where excitation of the PFT molecules is possible: 1) ultraviolet (UV) radiation of wavelengths shorter than 300 nm and 2) infrared (IR) radiation in the spectral band above 4μm: in the spectral range between 400 nm and 4μm, PFT is transparent (no absorption lines). Respectively, either a source of UV radiation, where PFT reveals the atomic absorption lines, or a far IR source, where strong molecular absorption lines were observed experimentally, is needed. Currently, no detailed UV absorption spectra of PFT compounds are available; IR absorption spectra of perfluoro-1,2,3-dimethylcyclohexane were obtained at ORNL (6 – 12μm) and the Sensor CAT (2 – 5μm). We believe that UV radiation is less advantageous for the purpose, for a number of reasons including the danger it represents for humans and little availability of inexpensive radiation sources, especially coherent, in the spectral range required; also, absorption by water vapor in atmospheric air limits the possible use of UV light in the spectral region shorter then 240 nm. Water vapor is responsible for strong absorption lines in the IR as well, especially between 2 and 3μm, 5 to 7μm, above 16μm. Fortunately, the IR absorption lines of PFT molecules are located in transparency windows, at 4μm and between 8 and 12μm, so that these wavelengths can be used for PFT vapors excitation and fluorescence detection. What is needed is an illuminator in the appropriate IR spectral range capable of exciting strong enough fluorescence to be detectable.

3. Excitation Source (Illuminator)
One may think of two basic sources for remote infrared excitation of PFT vapor:

(i) **A continuous broad-spectrum illuminator**, similar to a conventional IR searchlight, but intense enough in the spectral band of PFT absorption to induce fluorescence detectable on the background of the optical noise. A potential advantage of such a source is that one could expect it to be relatively inexpensive. At the same time, because in the spectral range of interest, PFT absorbs in narrow lines, most of the radiation from a broadband source will be wasted.

(ii) **A pulse IR laser resonant to one of PFT absorption lines**. While potentially more expensive, a laser source may be used from much larger distance. Its additional advantage is the availability of short-pulse output, which yields an important tool in fighting noise.

4. Proposed R&D
Our preliminary estimations show that both avenues deserve investigation as a potential basis for a new sensing device, affordable, compact, and capable of detecting PFT traces from large distances. The following steps are envisioned.

Stage I.
1. *Quantitative spectral analysis of the PFT compound in IR absorption and emission spectra as outlined above.*

2. *Determination of quantum yield and conversion efficiency of PFT luminescence.*

3. *Measurements of spectral density of thermal background radiation of urban and suburban terrain, as well as of the air, near the PFT fingerprint fluorescent lines.*

4. *Review of available IR detectors in the range of interest.*
At this point, available and potential *broadband and laser illuminators should be compared,* both in terms of their excitation capabilities and in terms of potential costs and application convenience. *The best illuminator will be chosen.* At the same time, available *detectors should be evaluated,* and suggestions made on the need for their further *development, redesign,* etc.

Stage II.
1. *Improvement/redesign of the IR detector.*

2. *Development of the complete sensing system.*

Appendix II

TRACER DETECTION TECHNOLOGY CORP.

PRODUCTS AND SERVICES FOR CORPORATE AND GOVERNMENT SECURITY

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TECHNICAL BRIEF

April 9, 2002

Background:

On March 28, 2002, Tracer Detection Technology Corporation (Tracer) presented to the National Institute of Justice (NIJ) and a panel of law enforcement representatives assembled by NIJ the results of Tracer's most recent work on Perfluorocarbon taggants (PFTs), specifically with the compound perfluoro-1,3-dimethylcyclohexane (PDMC). Tracer completed this work under NIJ Grant # 2001-LTBX-K005, and in collaboration with the New York State Center for Advanced Technology in Sensors Systems, a department of the State University of New York at Stony Brook (SUNY).

During Tracer's presentation of results, a representative from the Naval Research Laboratory (NRL), Dr. Robert Mowery, introduced a number of prepared slides, including "Selection of Taggant Candidates," delineating thoughts on four specific selection criteria. This Technical Brief is presented by Tracer Detection Technology Corp. to evaluate these four criteria, and show their relationship to Tracer's developments. For this purpose Tracer has also further consulted its SUNY collaborators, and drawn upon external PFT expertise developed by the US Department of Energy (DoE).

The Four Acceptance Criteria:

Tracer's technical evaluation concurs with that of our scientific sources, as follows. A copy of SUNY's discussion of the four issues raised by NRL is attached for reference, as is a copy of a paper prepared for the United States Environmental Protection Agency by Gunnar I Senum and Russell N Dietz of the Brookhaven National Laboratory, "The Global Warming Impact of Perfluorocarbon Tracer."

1. NRL expressed concern about compatibility of Tracer's objective to develop a "stand-off system" for detecting airborne PFT vapors in the IR, based upon the IR transparency windows of air at relevant wavelengths. NRL presented an IR transmittance spectrogram of air, "Atmospheric Windows," to support this concern.

   The wavelengths bounding PDMC's absorption energy in the IR have been shown to be approximately 3.8 and 4.3 um. On the spectrogram they presented, NRL abbreviated this as 4.2 um.

   NRL also placed an arrow labeled "4.2 micron" incorrectly at 2.6 um on their spectrogram. Tracer agrees that 2.6 um is not expected to be of utility due to air absorption. Similarly, if accurately located on the spectrogram, it is clear that a 3.8um to 4.3 um absorption (i.e. excitation) band substantially overlaps a major atmospheric transparency zone.

   Fluorescent emission at this excitation is expected by SUNY to be observable in the 8um – 12um zone, one comprising a broad and highly transparent window, according to NRL's slide. It is also important to note that the stated excitation/emission scheme is not the only spectral option open to Tracer for "stand-off" (or optical) detection.

2. NRL suggested that selected taggant candidates exhibit a vapor pressure of 67 mbar (50 Torr) or less at 25 deg.C. PDMC is acceptable by this criterion, as its vapor pressure at this temperature is 48 mbar.

3. "Short" atmospheric lifetime of days and weeks is suggested by NRL for candidate taggants. The rationale was not provided, but presumably picks up on a global warming theme that heat-holding concentrations in the atmosphere should decrease rapidly. The functional question appears to be "do PFT's pose a risk of increased global warming when used as chemical taggants?"

   To this question, in order to justify employing PFT's as taggants for detecting leaks from pressurized electrical cables and related applications, Brookhaven National Laboratory and the U.S. Department of Energy (DoE) has invested significant effort in elucidate the properties of these compounds, resulting in authorization by the U.S. Environmental Protection Agency (EPA) for PFT release to the environment.

   The DoE study (Senum and Dietz, attached) showed that per tonne of PFT released, the global warming impact is at the level of 5.4 millionths of a percent of the total functional burden of global warming agents produced, taking only the US production of non-PFT agents. As a kidnap recovery using PFT is likely to consume on the order of a gram of the taggant, the DoE study makes clear that any global warming on resulting from the use of PFTs as taggants shall be negligible.

Tracer is also concerned about ozone depletion issues, and here PFT's may present a certain advantage. A high rate of atmospheric reactivity as may be associated with a "short" lived compound could potentially be more problematic than the degradation process of a longer half-life material. Furthermore the molecular weight of PFT's such as PDMC means that their relative vapor density is expected to limit them to the lower atmosphere where, in conjunction with the reduced UV exposure, they are unlikely to participate in ozone depletion.

4. NRL suggested candidate taggants be non-toxic at ppm levels and below. PFTs are considered non-toxic at much higher levels, as attested to by their medical use as compounds for eye pressure adjustment during surgery and in artificial blood preparations. They are further used in "liquid ventilation" to inflate the lungs of premature babies.

A February 2000, toxicity review of PFTs by the Chemical and Analytical Sciences Division of the Oak Ridge National Laboratory indicated that these compounds are considered chemically and biologically stable, that health risk is limited, and that neither their use nor disposal appear subject to Federal regulation.

As to PDMC itself, Gleason, M N Gosselin, R E and Hodge, H C (Clinical Toxicology of Commercial Products, Baltimore 1963) rate its human lethal dose as more than 1 kg for a 70 kg (150 lb) man.

Conclusions and Recommendations:

1. Correcting the wavelength designation to a NRL slide supports Tracer's prior determination that IR fluorescence detection of PDMC is feasible and should be tested

2. The vapor pressure of PDMC fully conforms to stated NRL selection criteria.

3. The Global Warming Impact of PFTs has been shown to be negligible, and their environmental half-lives and vapor densities appear to be attractors from an ozone depletion avoidance standpoint.

4. The toxicity of PDMC (and PFTs in general) greatly exceeds *to the low side* the stated NRL toxicity criterion.

5. It is concluded that PDMC conforms to NRL selection criteria for environmental application and stand-off IR optical detection feasibility. In further consideration of the repeated successful use of PDMC in field operations, it is recommended that its stand-off detectability by optical methods be substantiated by additional testing.

SELECTION OF TAGGANT CANDIDATES

Perfluoro-1,3-dimethylcyclohexane C_8F_{16}. Vapor pressure: **48 mbar @ 25 °C.** Stable under normal conditions. No toxic effects observed (supplier data).

Conclusion:
PFT taggant conforms to three out of four requirements put forth by NRL researchers, with the remaining probably irrelevant for the intended use.

Indeed, according to NRL, the compounds are needed that:

(i) "avoid interference from atmospheric components."

It's somewhat too broad a condition; actually argued was the absorption characteristics. In this regard, the following takes place. The PFT absorption line suggested by us for exciting the fluorescence is a broad line centered near **4 μm** (3.8 – 4.3 μm) located within the atmospheric transparency window, near its right edge. The NRL viewgraphs that purport to challenge the feasibility of our proposal show a similar, but not identical, **4.2 μm** line of a different compound, Perfluoromethylcyclohexane C_7F_{14}; at that, this line is also placed erroneously, between 2 and 3 μm marks, thus creating a wrong impression of strong atmospheric absorption at the suggested by us excitation wavelength. On the other hand, the "fingerprint" fluorescent lines of PFT are in the range of 8-12 μm, where the atmosphere is virtually transparent. In this regard, another excitation option is to use a tunable CO_2 laser and select the pumping line in the atmospheric window 8-12 μm as well.

(ii) "that have appropriate vapor pressures, e. g. ...67 mbar or less at 25°C"

Vapor pressure of the PFT C_8F_{16} is 48 mbar.

(iii) relatively short atmospheric lifetime

The requirement is given with no explanation, so we would assume that it is to avoid the impact on the ozone layer. No environmental impact, however, should be expected because of the miniscule amounts of PFT used in tagging. The vapor is heavy and virtually doesn't diffuse to the upper atmosphere, where it can be decomposed by the solar UV radiation to produce fluorine interacting chemically with ozone.

(iv) "...nontoxic at ppm levels and below."

The most important feature of PFT is its non-toxicity for people. Also, it is colorless and odorless, i.e. undetectable without specialty technique.

Appendix IV

The Global Warming Impact of Perfluorocarbon Tracer

Gunnar I Senum
Russell N Dietz
Tracer Technology Center
Brookhaven National Laboratory
Upton, NY
October 13, 1998

Of increasing importance in intentional releases of compounds to the environment is their Global Warming Potential. Perfluorocarbon tracers (PFTs) are used in many applications, resulting in their intentional release to the atmosphere. These applications range from leak detection of PFT-tagged dielectric fluids in subsurface HPFF (high pressure fluid filled) electric cables to atmospheric transport and dispersion experiments. Tracers used in these applications must be chosen so as to minimize their global warming impact while maximizing their benefit in the intended use.

Chemical compounds are ascribed a Global Warming Potential (GWP) based on their ability to increase the temperature of the atmosphere. The GWP is calculated based on the radiative properties and atmospheric lifetime of a compound and normalized to carbon dioxide. Consequently, a larger GWP indicates a *potentially* greater effect in the warming of the atmosphere. Several chlorofluorocarbons have been phased out of use and newly designed replacements based on their reduced GWPs are now in use. A Global Warming Impact (GWI) can be ascribed to every compound released to the atmosphere based on the product of the GWP and its annual emission to the atmosphere. Table 1 lists many compounds with their GWPs and their GWIs. It is the GWIs that must be compared when assessing the effect on global warming of different compounds released to the atmosphere.

It is clear that the largest man-made emission to the atmosphere with the greatest GWI is carbon dioxide, primarily derived from it use in combustion/energy applications. The perfluorocarbon tracers (PFTs) have a large GWP, about 7000, but their annual emissions are quite low, resulting in a negligible Global Warming Impact. The PFTs, even with their high GWPs, are still the tracers of choice since they have also a low Tracer Global Warming Parameter (TGWP). The TGWP is defined as the product of the GWP and the tracer ambient background. This is a selection criteria for tracers with respect to global warming when designing a tracer application. For example, HFC-152a has been proposed as a tracer because it has a GWP of 140, compared to 7000 for PDCB (e.g., Vertrel 245). However when the tracer ambient backgrounds, in ppts, are used to calculate the TGWPs, then HFC-152a has a higher TGWP (75) than PDCB (8.4). Consequently, **Vertrel 245**, i.e., PDCB, would be the **tracer of choice**. The logic behind this is that the tracer with the lowest ambient background would require smaller releases (smaller GWIs) to be detectable above the ambient concentration.

It can be concluded that intentionally released tracers should make use of the most effective analytical procedures in order to measure down to the ambient background level of those tracers. This minimizes the amount of tracer released and consequently their Global Warming Impact.

Table 1
Global Warming Impacts

Compound	GWP (100 yr)	1996 US Emissions (m tonnes)	Use	Global Warming Impact GWP x Emissions (m tonnes)
CO_2	1	5.3×10^9	Combustion	5,300,000,000
Methane	21	3.1×10^6	Anthropogenic Sources	651,000,000
Nitrous Oxide	310	462,000	Anthrop. Mobile Sources	462,000,000
CFC-12	6,650	47,000	Auto AC, Chillers	312,550,000
CFC-113	9,300	16,000	Solvent	148,800,000
HCFC-22	1,350	93,000	Residential AC	125,550,000
HFC-23	11,700	4,000	HCFC Byproduct	46,800,000
SF_6	23,900	1,200	Insulator, Cover Gas	28,680,000
HFC-134a	1,300	22,000	AC, Refrigeration	28,600,000
CFC-115	9,300	3,000	Solvent	27,900,000
CFC-114	9,300	2,000	Solvent	18,600,000
HFC-142b	1,540	11,000	CFC Replacement	18,150,000
CF_4	6,900	2,000	Aluminum Smelting	13,800,000
CFC-11	1,320	10,000	Blowing Agent, Chiller	13,200,000
HCFC-141b	270	33,000	CFC Replacement	8,910,000
C_2F_6	9,200	200	Aluminum Smelting	1,840,000
HFC-152a	140	1000	Aerosol Propellant	140,000
PFTs[(1)]	**7,000**	**1**	**All Tracer Applications**	**7,000**
PFTs	**7,000**	**<0.001[(2)]**	**Dielectric Fluid Leaks**	**<7**

(1) Perfluorocarbon Tracers
(2) Estimated for annual DF leaks

Appendix V

TRACER DETECTION TECHNOLOGY CORP.

PRODUCTS AND SERVICES FOR CORPORATE AND GOVERNMENT SECURITY

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This report was provided by a Special Operations Team working with Tracer Detection Technology Corp. and is therefore substantially unedited.

After Action Report On Taggant Technology
Case # 1991-A

This case was the kidnapping of a 17-year-old boy in Mexico City in March 1998. The young man was kidnapped on the Barrancca Del Muerta on his way to School. The method was a rolling ambush with three cars. A blocking car in the front and rear with the car containing the snatch team on the left hand side. The victim was his associate drove off pistol whipped to the floor and the car with one man holding the boy down.

Our connection was through the family and we were in liaison with the counter kidnapping police from the state of Mexico. The unit has a good performance record and was brought into the case by the attorney general, allowing them the precedent to work inside the Federal Zone.

From intelligence it was determined that the gang was one that was known to the CKG and was led by an ex Special Forces Officer. The operations of the gang were extremely compartmentalized. The actual snatch team was a group of ex bank robbers that had been co-opted by the gangs second in command and then trained in the ambush technique in Texcoco area. They were subsequently captured with the victim's car two days after the actual kidnapping. Their interrogation led the police back to the gangs second in command. The CKG suspected police involvement and only they and the family knew our presence.

We originally contracted the equipment, taggant and technicians from and outside contractor and flew all into Mexico City with the CKG clearing them through customs as a lab crew on loan from the United States. We assembled the equipment and did a test run two days after they arrived. Utilizing a small amount of the Chemical we were able to ascertain that the taggant worked well in the environment of Mexico City. The Chemical actually worked to optimum since the chemical attached itself to the particulates in the smog.

Hour I

Actual operation began at 2000 hours on the next day where we marked the money ($500,000 USD in Pesos, bundled into 10,000 peso stacks) The money was all in 100 and 200 peso denominations. The marking took two persons 20 minutes to mark. The delivery was affected by one of my personnel.

The drop was a standard MO for this and many of the gangs operating in Mexico City. The vehicle was a newly purchased Pickup truck, all white. My operative was instructed to wear white shirt white pants. They had the number to an older model cell phone, which the gang had instructed us to buy. This is indicative of both the gang's expertise and the fact that there was police involvement. The older model cell phones are untraceable with the scanners employed by either the police or Gobernational forces. They have been mostly phased out but there apparently is a thriving business in the criminal community, providing them to the victims. We purchased from a shop in a questionable neighborhood.

Making my operative drive the Acapulco Toll road until their watchers had determined that no vehicles were following him affected the drop. At that point they instructed him to leave the toll road at a dirt road that adjuncted the blacktop. He was instructed to drive .75 kilometers then stop and leave the money in the black bag under a bridge abutment. This he did and then exited the area.

The young man was released in Chalco and given enough money to call home. Once he was reunited with his family we were ready to effect operations. He was released at 4 AM we were on the road by 5:30 AM. We went to the drop point and registered a hot reading then drove around at the direction of the police. For the first hour we had no signal. This I later found out was the Commandante's litmus test to see if the technology actually worked. Once he was satisfied that we could pick up the scent we were directed to Texcoco and to a specific house that we later learned was the gangs second in Commands domicile. We got a steady straight-line reading from approximately 100 meters. The reading was 26,000 PPB. We had begun receiving readings on the main highway 10 kilometers before we reached his house.

The next stop was a small Ranchero (walled village) about ten kilometers Southeast of Texcoco. Again we had peaks of varying intensities from 700 to 1500 PPB on the way there. There was heavy truck and car traffic on this high way. Once we pulled off the main road we went into the Ranchero where we were able to pinpoint two locations that were hot. The houses were so close together we were only able to say definitively it was somewhere in 5 to 6 houses. The readings on the machine were short spikes until we got next to the cluster of houses. This was approximately 14 hours after we had made the drop and 20 hours after I had marked the money.

We then were directed to a house in Texcoco that was in a better more affluent neighborhood. Here we got a real strong flat line reading. No mistaking it was generating from that particular house. We boxed the location from the four sides and verified that. The last place we were directed to was the Central Police Station. Here again we registered a strong flat line reading.

The machine at that time was operated on internal batteries and the laptop was as well. The technicians said they were losing power and we had to shut down operations. This was false they merely covered up the fact that they were tired and didn't want to be out any longer. We had been on the road at this point for nearly 29 hours.

Since the CKG had enough to effect the raids that they wanted we no longer needed the machine. At 2300 that night I accompanied the CKG in the assault on the principal location where we had the strongest reading. In the short firefight that ensued eight of the gang were dispatched and three captured. We were able to recover two thirds of the ransom. The Gang leader and two others escaped. There was police involvement. The State prosecutor was sitting on the floor counting his money when the door blew in. Subsequent investigation led to the arrest of all but one senior police officials and twenty patrolmen at the police station that had money from the ransom in their possession.

CONCLUSIONS:

A. Use my own people as the technicians

B. Back up power supplies and helium need to be in the vehicle

C. Accurate Intelligence cuts the trail in half. You must have an effective force to work with.

D. The Smog particulates helped hold the taggant close to the ground.

E. In urban areas it is important to realize the effect that vertical structures have on the scent. In some places it will raise and show up as a false signal two blocks over when it sinks or gets in a down draft.

F. The team leader needs to be a Spec Ops type who has finely honed hunting instincts. His interpretation is crucial to finding the trail.

TRACER DETECTION TECHNOLOGY CORP.
PRODUCTS AND SERVICES FOR CORPORATE AND GOVERNMENT SECURITY

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This report was provided by a Special Operations Team working with Tracer Detection Technology Corp. and is therefore substantially unedited.

After Action Report
December 2001

Guanajuato, Mexico

This operation was at the request of the family that the 72-year-old patriarch had been kidnapped in November. The family business is one of the largest dairy product producers in Latin America.

The Father had been kidnapped by six armed men outside one of the satellite stores that the family operates as a retail outlet. The kidnapping was at 8 AM in the morning and the modus operendi was similar to a gang that had completed two other kidnappings in the last six months.

Our contact was directly with the Administrator of Public Safety, of the State Police with the Special Counter Kidnapping Unit. The head of this outfit was formally trained at the FBI academy on some sort of exchange program. His unit and himself are very professional and success oriented. Understaffed, underpaid, and under equipped. They have had five kidnappings in the last year and five of them from October thru December. His estimation was that one was connected to the ERP and the rest were gangs that had moved their target area out of Mexico City to the more lucrative areas in the interior states.

We commenced by borrowing the Governors jet with the approval of the Attorney general and proceeded to move equipment and material as well as three team members to the operational area.

We arrived with the expectation that we would make the drop within seven days of our having received the material, which would have put us at the optimum range of shelf life on the material. Because we were uncertain as to the potency of the material we took extra precautions in its packaging and temperature during storage.

On the fourteenth day after arrival we were in process of ordering new material since we estimated that the material was at 25% potency. This is congruent with our first trial four

years prior. Unable to get the material made in time due to New Years and the demand for payment having been made, we decided to go ahead with the operation. This potentially narrowed our ability to track the material to an estimated 20 hours maximum.

The CKG had only an inkling that there were three personalities that might be involved, representing three separate criminal groups. Two were based in Celaya and the third was based in Quaretaro. A span of some 70 kilometers. We had advised the family and the CKG that it was best for us to be able to check out any suspected locations as soon as possible after the father was retrieved due to the short window that we would have of detection.

The Temperature worked in our favor since it was cold at night (30 to 40 degrees) and warming up to the mid 60s during the day. Our experience during the days we were waiting was that we could leave material overnight on an object and got our strongest readings around 10 AM.

The prevailing winds and the altitude were of a concern since there was a chance they would disperse the plume before we were able to follow it. Our prior experience led us to believe that we could hope for a good chance of detection in or near built up areas, but in the open country we had problems with the wind currents.

At 11PM approximately one hour after the drop of the money was made, we launched the tracking operation. Our intent was with the coordination of the CKG, was to move to the nearest chokepoint from the drop location. This had been pre-established with the state police during the reconnaissance phase.

We were in position for approximately two hours with no contact. We decided with the cooperation of the CKG to move closer to the drop location. This would put us on a mesa overlooking the intersection where the drop lie about eight kilometers to our south.

The machine was cycling about every three minutes. Our sensors picked up no traces coming down the main hardball from the 54 Toll road. This is the main artery for egress out of the area. The elevation on top of the Mesa is listed in the Topo as 5800 feet and the wind was blowing steady towards the Drop location to the Southwest. There were several ridgelines between the drop point and us. We immediately picked up a reading of 3800PPB. At first we thought it was residual from the site but the wind was in the wrong direction. We began to cast down the hardball and lost the trace immediately. Coming back to the top of the mesa we picked up a reading of 450 PPB. We began to drive back towards the Toll road in the direction of Celaya. We would get Small readings (under 500PPB) then lose it.

We had stopped at an intersection that was approximately 500 meters from the dirt road that led to the Drop location. At this point a red late model pickup came out of the intersection and turned north towards Celaya. We waited for fifteen minutes then began to drive along the same direction. Approximately 2 kilometers North along this road we

picked up our first reading. 3200PPB. The temperature outside was between 30 and 41 degrees varying. We would get spot contacts for the next hour as we moved north.

At the main intersection of the road to Celaya we got a reading on the road directly into town. Since we were getting only spot readings we surmised that they were leaking from the truck every time someone opened a window.

At this point we were directed to go to the suspected gang member locations and search them with the sniffer. All three locations had zero reading.

On the route from the last location we were passing a small barrio, located next to an irrigation canal when we obtained a small register 780PPB. This was 62 kilometers from the drop location. We cast on all four sides of the village and picked up a trail on the dirt road running east from the village along the canal. Very small readings. It was approximately 14 hours after the drop. The temperature was starting to rise into the 60's.

When we got to the end of the road it was the main hardball leading to the airport. This was later confirmed to be approx 4 kilometers from where the victim was released. We decided to retrace along the canal and got a serious reading 2100PPB. We stopped and got out and found along the road a plastic bag similar to the one we had put the ransom money in. I took it and set it so the sniffer was inside the bag and confirmed it was one of the bags. We had kept track of the vehicles that had passed us or we had seen driving along the road.

A white late model Dodge pickup had entered the road and driven past us just before we had turned around to retrace our steps. It later was matched to a vehicle that had followed the drop off vehicle to the drop location. The CKG arrived and they collected the trash on both sides of the road, large water containers (new) bags of trash, and some loose items. (The trash later proved to contain fingerprints of the victim and others.)

We went to where the victim was released and got another small reading. Adjacent to this location was a large private community. We followed the wall around its perimeter and on the Northwest corner, again received a reading. This was difficult since we had to monitor the wind directions each time we took a reading then box the up wind area. . We reported to the CKG and they went about obtaining a warrant to get inside the community. Bad news it would take until the next day before they could obtain them.

We decided to break for a meal. At this point we had been on the trail and in the vehicle for over 24 hours. WE went to the large shopping Center on the North side of Celaya. There are three banks, a Gigante, Sears, etc. In this complex, one of my staff joked that the kidnappers were probably here shopping by now with their loot. We left the machine running. WE came out about fifty minutes later and reviewed the log. Bingo, there had been seven spikes whilst we had been inside. As we were sitting there a man came out and put several packages in the trunk of a late model Oldsmobile just as the machine cycled a test. It was a high spike. The CKG were informed and followed the vehicle.

The parking lot was too crowded to get a reading off of individual cars, but we stayed for another three hours. Outside all three banks there was positive readings. The CKG later processed all the security camera tapes. They identified three individuals including the man in the Oldsmobile, cashing 500 peso notes.

At this time we were at the end of what we calculated our ability to track from any appreciable distance.

The CKG asked us to set up in the house they were using to be able to test some of the suspects that they were bringing in. As we were setting up three of their officers came in and we got a positive reading. This was unnerving until I realized that one of them was the officer that had driven the money to the drop site and I had smeared him from stem to stern with the taggant. It was now 40 some hours later, two showers and a change of clothes and we were still getting trace readings off him. They were unable to bring in the suspects so at 1600 on the second day I terminated our operation.

CONCLUSIONS:

- The material has a shelf life of 16 days that we know of.
- The ability to interpret the signals is paramount to successfully tracking.
- Close cooperation with the CKG helped us eventually track the gang.
- The cold night helped preserve the deteriorating taggant until we could get to the location.
- In the open terrain the wind and how it interacts with terrain features is a very important aspect to keep in mind.
- A hand held device would have allowed us to search individual cars and locations surreptitiously.

APPENDIX – GLOSSARY OF TERMS

Tracer:	**Tracer Detection Technology Corp.**
SUNY:	**State University of New York**
Sensor CAT:	**Center for Advanced Technology in Diagnostic Tools & Sensor Systems at the State University of New York at Stony Brook**
N.I.J.:	**National Institute of Justice**
PFT:	**Perfluorocarbon tracers/taggants**
GC/ECD:	**Gas Chromatograph augmented with an Electron Capture Detector**
PFDMCH:	**Perfluoro-1,3-dimethylcyclohexane**
CATs TUBES:	**Capillary Adsorption Tube Samplers - Passive capture tubes used for non-realtime detection**
CTG:	**Mexican Counter-Kidnapping Group**

Grant # 2001-LT-BX-K005
(Grant Period: 8/01/01 to 1/31/02)

	Revised Budget	Final	Difference
Personnel	36,000.00	36,000.00	0.00
Travel	578.00	745.19	167.19
Other costs			
Rent	882.00	855.69	-26.31
Phones	800.00	937.00	137.00
Printing/Messenger	280.00	246.46	-33.54
Postage	20.40	47.73	27.33
Utilities	800.00	1,274.33	474.33
SUNY SB (NIJ)	35,000.00	35,000.00	0.00
(Match)	16,000.00	16,000.00	0.00
Equipment	25,440.00	24,673.60	-766.40
Project Total	115,800.40	115,780.00	-20.40