Chapter V

TAGGANT COST REVIEW

TABLES

FIGURES

Chapter IV

TAGGANT COST REVIEW

OVERVIEW

A detailed review of the potential cost and economic impacts of the proposed taggant program was conducted in parallel with the safety and utility segments of the study. In this analysis, the assumption was made that the taggants work and are safe to put in explosive materials. it was furthermore assumed that the current incompatibilities observed between the 3M identification taggant and one type of smokeless powder, as well as one type of cast booster material, would be resolved in a way which has no additional cost impact. The various cost elements were estimated by: '

- **drawing on existing studies and testimony; and**
- **interviewing the identification taggant manufacturer, explosive and gunpowder manufacturers and distributors, users of explosive materials, law enforce ment personnel, and sensor instrumentation engineers.**

Other important economic issues were addressed in parallel with the development of the program cost. The addition of taggants to explosives has a potential cost impact to an industry in which explosive-type decisions are frequently made on an economic, rather than performance or brand loyalty, basis. An additional taggant material cost issue is that raised by the probable monopoly of supply by one company, particularly by 3M for the identification taggants. The question of assuring price and taggant availability also required attention. Introduction of taggants into the explosive fabrication process will cause changes in the manufacturing process, due both to possible tooling costs and to the labor costs associated with purchasing, controlling, and using the taggants. Other, one-time costs are associated with product requalification tests for safety, potential costs for waste disposal equipment, and added plant capacity to make up for lost productivity.

Identification taggants require additional recordkeeping by the manufacturer, by wholesalers and distributors, and by the retail sellers. There are law enforcement costs associated with the recovery and tracing of identification taggants from explosions and with the subsequent followup process. These costs must, however, be compared with the cost of current law enforcement practices.

Detection taggants require a sensor and a system to sample and convey the air from the sample item to the sensor. The sensor and sampling system requires operation and maintenance, although it is possible that current security personnel could operate the additional equipment at an airport, for instance. There is an additional potential cost associated with possible delays raised by false alarms in the detection system. Significant false alarms could cause enough ill-will (in addition to high costs) to lead to the abandonment or curtailed usage of detectors in situations such as airports.

A final cost aspect which must be considered is the economic effect of a taggant program in which only selected explosives are required to be tagged. In the cost-conscious commercial explosive industry, that could eliminate certain products or companies from the marketplace, perhaps resulting in significant local unemployment.

Due to the fact that the identification taggants have progressed further down the development path, the relative precision of the cost estimates associated with their introduction into explosives is expected to be greater than the estimates of detection taggant and related sensor costs. The precision of each estimate is indicated during the course of the cost analysis discussion.

This cost analysis by OTA has been an intensive, short-duration study. Of necessity, the study was accomplished by drawing on existing studies from a wide variety of sources and by a limited number of onsite interviews with industry and Government. Discussion with industry included various explosives manufacturers and BM, the taggant manufacturer. Various user types such as mining companies (underground and surface), construction firms, and quarry operators were also visited. Extensive discussions were also held with the Aerospace Corp. (the taggant program development contractor), with the Institute for Defense Analysis, with Management Science Associates, and with consumer groups such as the National Rifle Association and the National Muzzle Loaders Association. Government agencies with whom detailed discussions were held include the Bureau of Alcohol, Tobacco, and Firearms (BAT F), the Federal Aviation Administration (FAA), the Department of Commerce (DOC), the Bureau of Mines (BOM), and various Department of Defense agencies.

Various degrees of uncertainty exist in costing out the taggant program, as little test data exists and some potential manufacturing process applications are undefined. Table 29 illustrates the qualifications of the estimating basis for the taggant program, indicating the status of pilot testing and the OTA understanding of the manufacturing processes required to implement taggants. On the right side of table 29 is set forth, in general terms, the method for estimating utilized, such as direct estimating, Aerospace Corp. analysis and assumptions, the Institute of Makers of Explosives (IME) member estimated inputs, Sporting Arms and Ammunition Manufacturers' Institute (SAAMI) estimated inputs, etc. The particular methods and data sources utilized are documented throughout this study where appropriate.

Table 29.–(lualification of the Estimating Basis for Taggants

			Etimating, basis		
Type explosive	Pilot tested	Taggant mfgr process understood	Process labor	Process tooling	Other capital expenses
Cap-sensitive packaged explosives	Yes	Yes	Direct/ estimate Proprietary detail estimate available. I ME member inputs.	***Direct estimate***	***Direct estimate*** Nonrecurring Requalification of products.
Cast boosters	Yes	Yes	Aerospace analysis/ assumptions		Waste disposal if additional waste due to "unacceptable contaminated tag batches
Smokeless powder	Underway	Yes	Aerospace analysis SAAMI estimate.	Equipment required: storage bins, hoppers, equipment for weighing, packaging, transferring tag samples,	
Black powder	Yes	Yes	Goex Study storing • security • administrative & records • mfgr, process cleanup		Investment offset losses in productivity.
Detonating cord	Planned	No	Aerospace assumptions,	Tooling. • Design required (no effective equipment currently available .	Cost of taggant Inventory Including the cost of money
Blasting caps	Planned	No	Aerospace assumptions	Significant cost • expected– new machine must be designed.	

'Aerospace estimates utilized and OTA survey inputs

SOURCE Off Ice of Technology Assessment

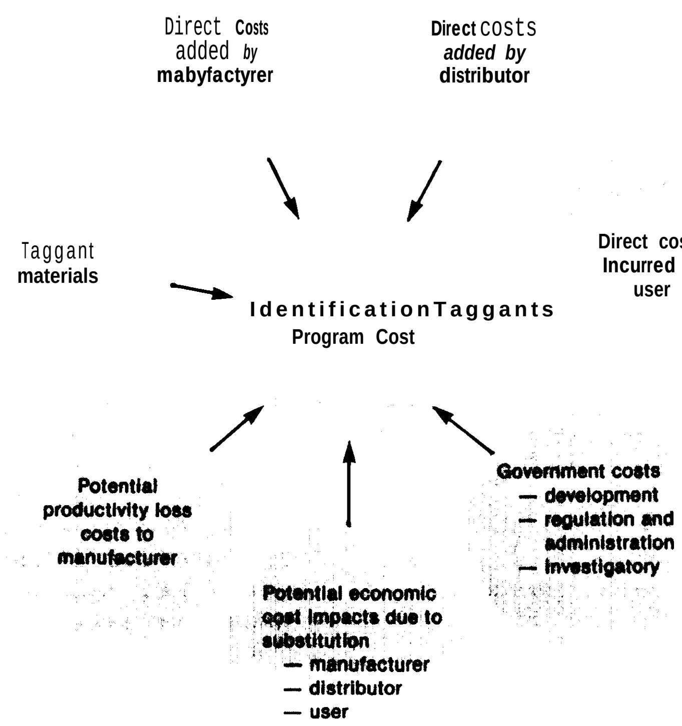
The primary methodology utilized in this cost analysis was to translate all program costs, both nonrecurring one-time costs and recurring costs, to annualized values. Capital investment costs were annualized over a 10-year period at an interest rate of 10 percent. This method was utilized for all initial expenditures (requalification, waste facilities, etc.) with the exception of tooling costs estimated for detonators and blasting caps, which were written off in a 5-year period at 10-percent interest.

The taggant program costs vary substantially as a function of the level of implementation of the program. **In this study, an** OTA identified baseline program was assumed for baseline cost estimates, and the parametric variation of the costs examined as a function of higher and lower level implementation plans. Cost estimates were also generated for the implementation program proposed by BATF.

All cost data and program estimates in this report are stated in fiscal year 1979 **dollars to assure consistent treatment. A list of taggant program cost elements was developed** to permit a comprehensive framework for treating all potential costs and resources impacted by the taggants program. Figure 10 illustrates the general sources of costs potentially involved in the program, while a detailed list of potential cost elements is shown in table 30.

For purposes of exposition throughout this cost impact assessment, a baseline set of conditions or assumptions is utilized in the determination of a total program estimate. These are shown in table 31. This baseline program

Figure IO.—Schematic Illustration of General Cost Element Sources



SOURCE Office of Technology Assessment.

Table 30.–List of Taggant Program Cost Elements

Taggant materials
Idenhflcahon taggants
Detection taggants

Detection sensor-related costs
Sensors
Sensor sampling and transport instrumentation
Operations and maintenance
Cost of false alarms

Explosive and gunpowder manufacturing costs
Nonrecurring cost
- Tooling
- Storage
- Product requalification- safety testing
- Waste disposal facilities
- New Investment to offset production losses

Recurring costs
- Manufacturing process labor
- Record keeping
- Quality control
- Production losses
- Waste product line
- Inventory costs
- Administration expense

Markup

Distributor costs
Record keeping
Storage
Markup

User costs

Other costs
Government administration
Taggant program development
Investigative costs

SOURCE Off Ice of Technology Assessment

Table 31 .–Baseline Taggant Program Configuration

. Encapsulated identification taggants
- Explosive weight or units to be tagged and tagging concentration

Category	Units/yr		Concentration
Cap-sensitive packaged explosives	325,000,000	lb	.05%
Boosters	6,000,000	lb	.1 %
Black powder	400,000	lb	.05%
Smokeless powder	5,000,000	lb	.05%
Detonating cord	500,000,000	ft	5 tags/in.
Blasting cap	84,000,000	units	50 mg

. Identification and detection taggants
. 1,500 sensors to be deployed
- Sensor mix. M S 10°/0, I MS 90°/0
. 10% taggant contamination permitted
- "Composite tag" permits rework of previously tagged material
- Days production of each type/size explosive (date-shift basis)
- New taggant code for each

SOURCE Office of Technology Assessment

includes several provisions which, OTA believes, would do much to hold down costs without a significant reduction in the utility of the program: blasting agents are not tagged; the identification taggant code is changed only when the date, shift, or product changes (resulting in some code numbers corresponding to a large batch size and others to a small batch size); and a special "composite code" is used for taggants added to already tagged material (permitting rework without removal of previous tags). The special composite code taggant would be added to material with more than 10-percent cross-contain ination; such a taggant would indicate that the material used was a composite and that taggant codes other than the specific composite code should be ignored.

Although confidence levels are relatively high for certain elements of costs, particularly for the identification taggant program, other program elements are subject to considerable uncertainty (particularly the number and types of sensors to be employed in the detection taggant program). Attention is called to the baseline assumptions associated with each cost element throughout the discussion of cost.

In the following section the costs for the taggant materials are developed. This is followed by detection taggant sensor-related program cost estimates. The potential cost increases occurring during the explosive manufacturing process and at the distribution level are then addressed. The potential cost impact(s) to the users of explosives are subsequently discussed. Other cost impacts, including the cost contribution by Government for administration, investigation, and taggant program development, are set forth in the next section. A gener-1 synthesis and summary of the taggant program cost estimates follows, with the relative precision or accuracy of the estimates discussed after that, including aspects of cost uncertainty and program cost sensitivity. The adequacy of the current cost data and suggested further research are briefly discussed in the last two sections, respectively,

TAGGANT MATERIAL COSTS

The cost of both the identification and detection taggant material is heavily influenced by the amount of explosive material to be tagged, the form of the tagging material, and the concentration levels. Material cost estimates are developed for the baseline program described above.

Identification Taggants

The annual quantity of explosives produced in the United States, shown in table 32, was estimated based on data obtained from IME, BATF, Aerospace Corp., BOM, and DOC. An unresolved problem exists with respect to the production of cap-sensitive packaged high explosives. The basic difficulty stems from the method of reporting data in the surveys collected by both BOM and DOC, Some "unknown" quantity (both permissible and other high explosives) of cap-sensitive explosives is reported as included in unprocessed ammonia nitrate and "al l other purpose" categories in order to avoid disclosing individual company data. Since the data are masked to protect the marketing positions of explosive manufacturers, the uncertainty in annual quantity will persist, For purposes of this study, the quantity of 325 million lb/year (as adopted by Aerospace) wil l be used as the baseline condition.

A second variation concerns the level of black powder produced. Approximately 2.5 m i l l ion lb of black powder are produced per year in the United States, but the majority is used as a raw material in other fabrication processes, such as fuzes. Approximate y 400,000 lb are sold directly to the consumer; this amount is included in the explosive materials to be tagged. Table 32 shows the production quantity, the concentration of unencapsulated taggant material suggested by the BATF/ Aerospace team, and the resultant quantity of unencapsulated taggants required annually,

Price estimates, obtained from 3M as a function of annual taggant production, are shown in figure 11 The estimates quoted are for unencapsulated taggants produced in 5-lb lots and assume a firm order for a minimum of 2 years. The 150,000-lb level is a result of a detailed leadtime study conducted under contract to the Aerospace Corp. The target price and worst case estimates for the 75,000- and 100,000-lb levels were provided by 3M in response to an OTA request. The range of prices reflects the fact that less time was available for the 3M estimates than the original 150,000-lb level, resulting in some uncertainties. These target prices have all been through a rigorous price review within the 3M corporate structure and represent the firmest commitment possible short of a production contract.

Table 32.–Annual Taggant Requirements

Explosive category	Quantity to be lagged	Concentration level (unencapsulated)	Annual taggant requirement pounds (unencapsulated)
Cap-sensitive packaged high explosives	325.000.000 lb	0.025%	81,250
Cast boosters	6.000,000 lb	005 %	3,000
Smokeless powder	5,000.000 lb	O 025%	1,250
Black powder	400,000 lb	0.025%	100
Detonating cord	500,000,000 ft	5 tags/in,	160
Blasting caps	84,000.000 caps	50 mg each	4,620
			90,380

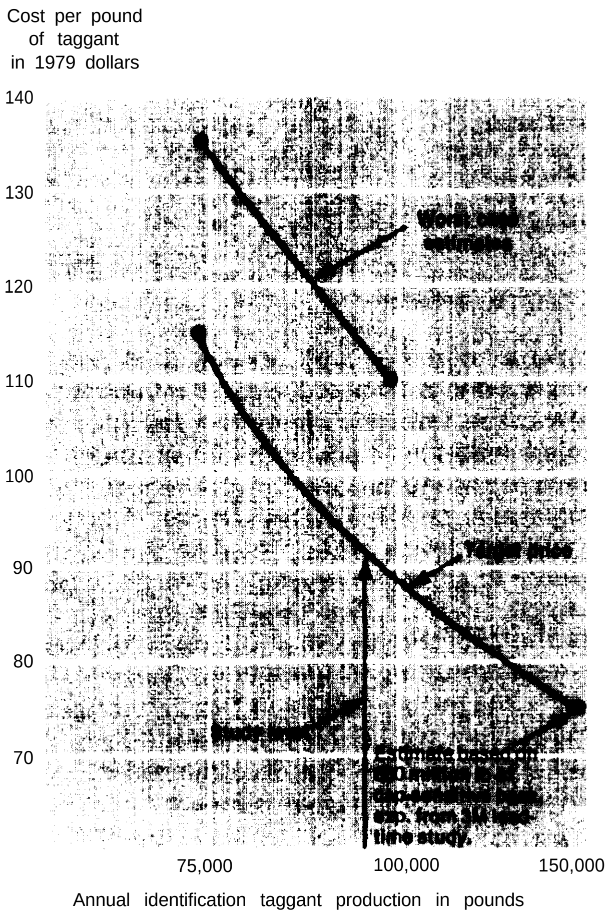
SOURCE Of ficeof Technology Assessment

Assuming linear extrapolation between the data points, the price for unencapsulated identification taggant material was estimated by OTA (from figure 11) to be approximately $93/ lb for the estimated **90,000 lb of taggants to be required annually. This cost figure assumes production** in 10,000-lb lots. In cases where most lots are substantially smaller, taggant costs per pound of explosives might rise.

This figure is for unencapsuiated taggants, while the baseline OTA program assumes the taggants are encapsulate? in an opaque polyethylene wax. The 3M technical people furn i shed an estimate of the cost of encapsulating the taggants in polyethylene wax, but were unable to estimate the cost impact of using an opaque polyethylene wax. Based on the above data, OTA estimated that it would cost $55/lb

Figure 11 .—3M Identification Taggant Cost Estimates

•5-lb tag lots •Unencapsulated •2-year minimum required



SOURCE: Office of Technology Assessment

for opaque encapsulated taggants, as the baseline tagging level is 0.05 percent by weight of *encapsulated* taggants, and the encapsulating material weighs the same as the unencapsulated taggants. ($93 for 1 lb of encapsulated taggants, plus $17 **for 1 lb of encapsulating material, plus the process, equal $110 for 2** lb of encapsulated taggants, or $55/l b.) This corresponds to 2.75 cents/lb of cap-sensitive explosives for the identification tagging material.

IME and a number of other individuals and organizations have based their cost estimates on a price of $200/lb of encapsulated taggants and an additional library maintenance fee of $100/year per unique taggant species. This identification taggant cost has been clearly identified by 3M as the cost of taggants produced in their current pilot plant, which is labor intensive, if there is no program legislated to tag commercial explosives. It does not represent a potential cost figure if a taggant program is legislated, Details of the cost of taggants, as a function of total quantity needed, were given above. No additional fee would be required for library maintenance.

Detection Taggants Materials Costs

The Aerospace Corp., as part of its taggant contract effort for BATF, has put considerable effort into the development of molecules for detection taggant purposes. As a result of investigation of the properties of several hundred potential molecules, five chemicals are currently considered excellent candidates for the program. These perfluorinated cycloalphones are:

- PDCB — perfluorodimethyl cyclobutane,
- PMCH — perfluoromethyl cyclohexane,
- PDCH — perfluorodimethyl cyclohexane,
- PFD — perfluorodecal in, and
- PS P — perfluorohexyl-sulfur-pentafluoride.

The final selection of a particular detector taggant will depend on the results of compatibility testing, efficacy in conjunction with the detection taggant sensor, price, and availability.

The microencapsulated detection taggant would be directly incorporated as a free-flowing powder in commercial explosives and gunpowder. Since part of the chemical selection criteria includes a low or negligible utilization of these materials in standard manufacturing (to minimize false alarms due to ambient air background), standard cost/price data currently available was supplemented by requests by the Aerospace Corp. to a number of companies for budgetary pricing-type estimates at quantity levels of 200,000 lb/year. A range of estimates was received for both the cost of the detection taggants and for the encapsulation process. Taking these values into account, as well as adjustments for process yield, the following range of estimates was made by OTA.

Lower end of range	$22 20/lb
Medium	40.00\lb
Higher end of range	58.15/lb

For purposes of the baseline study OTA has utilized the medium cost of $40/lb of encapsulated detection taggant. The Aerospace Corp., in their inflationary impact study, estimated conservatively a value of $65/lb, based on early data. With the more recent quotes it is reasonable to estimate a lower value for detection taggant material. Uncertainty as to the value chosen remains due to the following factors:

- final taggant selection,
- final contract price,
- cost of encapsulation,
- the weight effect of the encapsu l at ion process, and
- the final yield ratio of the encapsulant ion process,

Since the detection taggant program remains in the early stages of development, uncertainty will persist in this value. Variations from this value will be examined in the cost sensitivity analysis. The relative significance of the variations of the detection taggants cost is not expected to greatly perturb the overall taggant program cost estimates.

Cost and Supply Guarantees

The identification taggants currently proposed to be used are manufactured only by 3M and are a proprietary product manufactured by a proprietary process. In addition, a significant public overhead cost would have been incurred before the compatibility of explosive materials with the taggants could have been demonstrated, Mandating the addition of identification taggants to explosive materials would, therefore, ensure a monopoly of the Government-mandated market for 3M, at least for a period of several years. Under such circumstances, development of a mechanism to regulate the virtual monopoly of the identificat ion taggant market that 3M would enjoy is highly desirable. While several suppliers are capable of supplying the vapor detection taggant, production in the necessary quantity will probably require significant capital investment, much of which would be amortized by the taggant program. It is therefore desirable to have a mechanism that will ensure the price of the vapor taggant material as well

A number of mechanisms are available to regulate the price of taggants, including:

- a price level set by Congress in the enabling legislation,
- regulation as a public utility,
- licensing by 3M of competitors,
- a multi year, fixed-price contract, and
- a free-market price, regulated only by the possibility of competition or sanctions if prices get too high.

The free-market mechanism is probably unacceptable, given the long time needed to either develop and qualify an alternative taggant or enact sanction legislation, Legislation of a price or use of a regulation mechanism similar to that used for public utilities would be an awkward, time-consuming process for a product whose total annual value would be on the order of $11 million.

Licensing is not only disagreeable to 3M, but it is probably not cost-effective. The cost of the taggant material includes a component for amortization of the taggant production facility, as a new facility must be built and the primary market for identification taggants would likely be the mandated explosives market, The process that 3M plans to implement is capital-intensive. Licensing of other manufacturers would therefore require the construction of facilities for the licensee, in addition to a new 3M facility, resulting in a substantially higher total cost.

A long-term contract may be the most effective mechanism. I n tact, the 3M cost estimates are conditional on firm orders for a 2-year period, although 3M is willing to consider contracting periods of up to 5 years, The details of the contracting mechanism have not been addressed by this study, although there may be some advantage to a single contracting agency (presumably within the Government), rather than separate contracts with each manufacturer of explosives and gunpowder. In addition to saving the cost of multiple contracting, the single-contract concept would limit the amount of information available to 3M on numbers of product lines and production quantities of explosives, a matter of some sensitivity to the explosives manufacturers.

Assurance of availability of a taggant supply is a related issue. A number of approaches are possible, including:

1. manufacture and maintain a large inventory of taggant materials, either by the manufacturers directly or by the Government acting as purchasing agent; a 6-month supply should certainly be adequate;
2. develop redundancy by constructing a backup manufacturing site for taggants; and
3. utilize the discretionary power of BATF to provide relief from the legislation in cases of emergency induced interruption of supply.

A detailed tradeoff would be necessary to decide the relative merits of options 1 and 2. Option 2 shares the cost impact of additional capital-intensive construction identified for the licensing option considered above. The acceptability of option 1 to the explosives and gunpowder manufacturers may be heavily weighted by who bears the cost burden of maintaining the 6-month inventory. Option 3 carries with it a possibility of weakening the utility of the taggant program, and would probably be implemented only if necessary; for instance, if a manufacturer ran out of taggants and would otherwise be forced to stop product ion.

In the OTA baseline costing estimate, the 6-month inventory option was assumed, and manufacturing cost estimates include the cost of the taggant inventory, as well as the cost of money to carry the inventory.

SENSOR-RELATED COSTS

The detect ion taggant sensor program is in the very early stages of development. To date, most of the effort in the detection area has been devoted to the vapor taggant selection process. Because detection taggants are still in an early development phase, a relatively high degree of uncertainty exists in several of the principal cost-driving factors. The sensor(s) development and product ion unit cost estimates are one area, and the quantity of sensors to be deployed is another. Table 33 sets forth the major qua l if i cat ions which underlie cost estimates of the sensor program. Three systems are current l y undergoing development by the Aerospace Corp.: the continuous electron capture device (CECD), the ion mobility spectrometer (IMS), and the mass spectrometer (MS). Performance specifications are severe for each of these canal i date opt ions including sensitivity at the parts-per-tril lion level and low (0.01 percent) false alarm rates. Parts lists for each of these systems have been identified and priced by Aerospace Corp. instrumental ion engineers and scientists, Commercial engineering "rules-of-thumb" have been utilized in estimating production price levels. Development cost budgets and outyear forecasts totaling on the order of $2.5 million have been estimated for advanced engineering development. The estimates, by the very nature of a development program, assume that development proceeds smoothly and without major redirect ion of design activity. In addition to the total number of sensors likely to be deplovecl, uncertainty exists in:

- the development cost,
- the production unit cost,

Table 33.–Qualification of Estimating Basis for Sensors

	Continuos electron capture device	Ion mobility spectrometer	Mass spectrometer
General availabilty of technology	Currently utilized in lab situation– Brookhaven Breadboard	Commercially available 5 years– 50 currently in use	High-cost laboratory model in use–no commercially available that meets cost and performance requirements
Taggant program status	Design of field Instrument in progress	Off-the-shelf PC-1OO Instrument IS being characterized for candidate taggants	Preliminary design underway for low-cost field unit
Parts (materials) identified and estimated by Aerospace	Yes	Yes	Yes
Taggant sensor production cost estimated with engineering rule-of-thumb factor applied to material costs	Yes	Yes	Yes
Quantities to be Implemented in a national program	Quantities depend on scenario selection–also decision to purchase Instruments rests with a large and varied user community–airports, courthouses, nuclear reactors, nuclear weapon centers, military communication centers, national shrines, Government office buildings, etc –quantities are uncertain and open-ended		

SOURCE Off Ice of Technology Assessment

- the system or systems actually employed, and
- the relative mix of systems to be deployed if several successful canal i dates emerge.

Numbers of Sensors Needed

Estimates of the total quantity of sensors likely to be deployed in the field are further subject to a wide range of uncertainty, as the decisions must be made individually by a large number of organizations, although regulatory a u t horities s u c h as FAA and the Nuclear Regulatory Commission could potentially represent customers for large numbers of sensors, The target to be protected must be high-valued and subject to control ted-access. With the exception of checked baggage, it is unlikely that any location that does not now have a guard would employ a detection taggant sensor. Likely targets for bombers, and likely locations for sensors, include airports, nuclear reactors, nuclear weapons centers, military communications centers, Government build i rigs, and computer centers. There are approximately **620 air ports in the United** States, **using** approximately 400 X-ray machines to scan carry-on luggage There are **70** nuclear power station~, and thousands of Government buildings of one type or another. Police bomb squads may also use portable sensors for investigation of bomb for all threats.

In the baseline program identified by OTA, a total of 1,500 **sensors was assumed** deployed. That number would include one sensor each for passenger screening, carry-on baggage, and checked luggage for each current X-ray machine stat ion, as well as 300 for protection of other high-value targets. l-he low-level program assumed 800 sensors, 2 each for each current X-ray station. The high-level program assumed 5,000 sensors, enough for all centrolled-access transportation facillties nuclear power-plants, important Government buildings, and portable police use

Sensor System Related Costs

The annual unit system cost for the sensors, including installation, maintenance, and false alarms, is shown in table 34. Since each point of controlled access where detection sensors are contemplated is already manned by personnel (who check entering personnel or search baggage), direct operator costs are not included for the baseline case. Excess false alarm rates would possibly be a cause for adding personnel, Training would be accomplished by the detector instrumentation company and occur either at the company as part of an operator training seminar or at the time of equipment installation. Maintenance costs for al l of the canidate systems are estimated at 10 percent of the hardware investment cost.

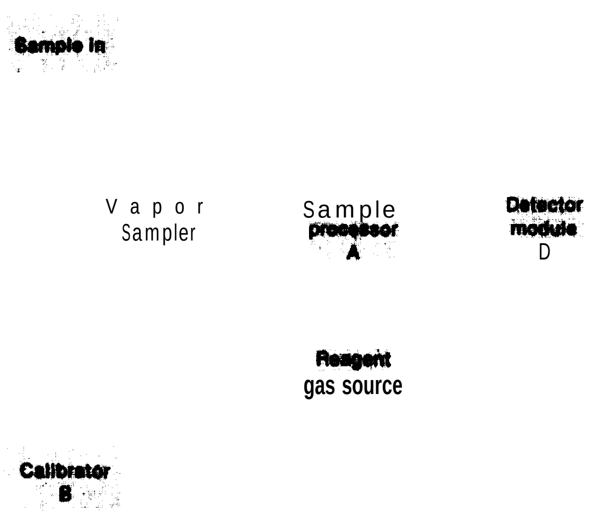
Table 34.–Vapor Taggant Dotoctor System Cost (annual cost per unit)

Hardware investment	Continuous electron capture device	Ion mobility spectrometer	Mass spectrometer
Cost per unit	$12,355	$15,160	$35,270
Installation and checkout	500	500	500
Hardware subtotal [a]	12,855	15,660	35,770
Annual cost of investment per unit[b]	2,082	2,537	5,795
Annual maintenance	1,236	1,516	3,433
Cost of false alarm@ .01% rate	0	0	0
Total annual cost per detector	$3,318	$4,053	$9,228

a Includes cost of training operating Personnel
b Estimated **10-year** life and 10 percent interest rate

SOURCE Office of Technology Asessment

Figure 12.– General Functional Network for Vapor Taggant Detector



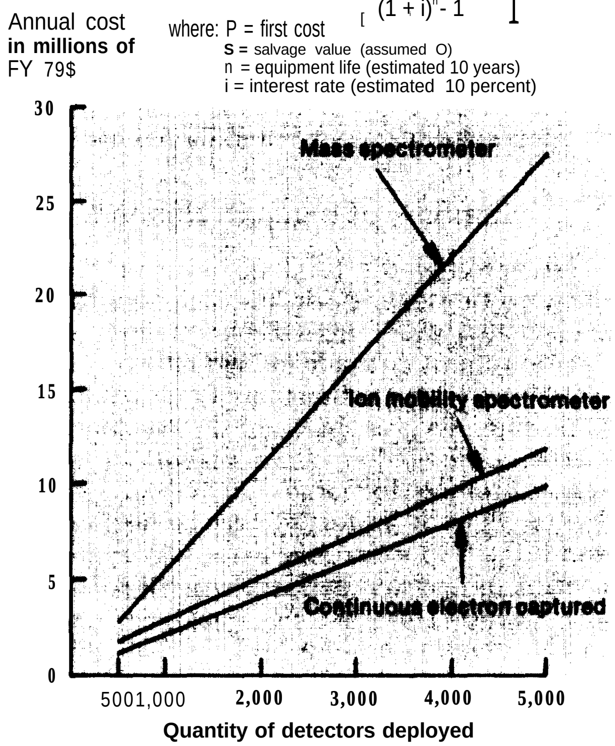
Total Cost A + B + C + D

SOURCE: Office of Technology Assessment.

Figure 13.—Estimatecl Annual Vapor Taggant Detector Cost v. Quantity Deployed

• Hardware cost only
• Annual cost = $P - S\left[\frac{}{(1+i)^n - 1} + i\right] + SI$

where: P = first cost
S = salvage value (assumed O)
n = equipment life (estimated 10 years)
i = interest rate (estimated 10 percent)



Mix of Sensors

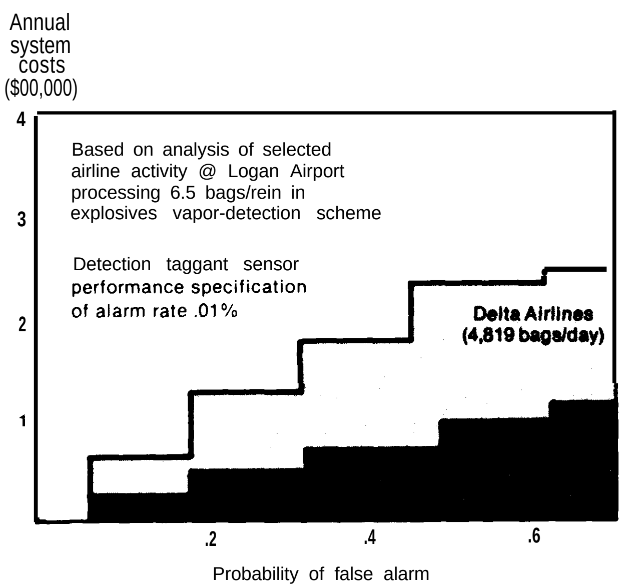
Development of the CECD, IMS, **and** MS sensors is expected to continue **in a parallel fashion. A system type would be eliminated if demonstrated to be infeasible. A** mix of possible sensors in the field is likely (given feasibility demonstration) since each instrument type would be found to offer advantages in given scenarios for performance (specificity, threshold, etc.) and costs (acquisition and operation and maintenance). The baseline program assumes a total of 1,500 sensors is deployed, 90-percent IMS and 10-percent MS.

The annual cost per sensor for this mix is approximately $4,580. In the cost synthesis section program costs have been estimated for various levels of implementation of sensor system to fit various utility levels examined in this study.

False Alarm Costs

False alarm response costs have been examined by FAA as a function of the false alarm rate for various technical approaches including explosive vapor detector schemes. The FAA study examined two airline operations at Logan Airport, Boston, as a basis for the operational scenario. As false alarm rates increase, so do the number of hand-searchers required and, therefore, the cost of operation. The results of that analysis, adjusted for the taggant vapor sensor, are shown in figure 14, where estimated annual cost impact for each of the airlines is shown as a function of the vapor detector false alarm rate. Incremental costs are incurred in a stepwise fashion at alarm rates greater than 0.05 percent (1 in 2,000). Since the performance design specification for the taggant sensor false alarm rate has been established at 0.01 percent (1 in 10,000), no false alarm costs are expected if this performance goal is realized. Cost level impacts reflect the particular operational activity characteristics of Logan Airport and would not necessarily reflect nationwide characteristics. Discussions with FAA personnel indicate that nationwide cost effects due to false alarms would be less than that reflected for the Logan scenario; costs of false alarms, on a national average, would probably not be significant at rates as high as a few percent, the current false alarm rate for airport magnetometers.

Figure 14.—Estimated Cost of False Alarms v. False"Alarm Rate



SOURCE: Off Ice of Technology Assessment

The cost of false alarms can also be calculated as a function of the cost per bag checked. At a rate between 0.05 and 0.175, the estimated cost of increased inspections due to false alarms is approximately 2.8 cents/bag at Logan Airport. At an annual level of 300 million checked bags per year in the United States, the estimated cost of false alarms due to checked baggage alone would be approximately $8.4 million. As noted, the cost estimate for Logan is considered high for purposes of estimating national levels; nonetheless, the potential cost due to false alarms would be a significant cost impact when considered in absolute terms. Since the cost of security checks at airports are ultimately passed on to the airline customer, the direct per capita costs would be minimal. At an average of 1.5 bags checked per passenger the per capita annual cost for the above conditions would be on the order of 5 cents. A high false alarm rate could lead to delays in the departure of aircraft, with significant losses to both airlines and the delayed passengers.

EXPLOSIVES AND GUNPOWDER MANUFACTURING COSTS

The value-added costs of the taggant program that occur at the explosive manufacturing level are addressed here. As has been alluded to earlier, the manufacturing process implacations for tagging implementation are best understood for cap-sensitive packaged high explosives where pilot-plant tests have been accompl ished. The tagging implications for detonating cord and detonators, conversely, are only addressable in a general way. As no feasible designs have been set forth for the required tooling, and engineering design and analysis have not been accomplished, the implications for blasting cap design remain uncertain. Because the OTA study effort was time-constrained, the major survey emphasis was placed in the area of cap-sensitive packaged high explosives. The estimates for cap-sensitive manufacturing costs are based on discussions with the major manufacturers. Some of these estimates are applied to other explosive types where appropriate. Preliminary estimates and analysis by the Aerospace Corp. are also utilized as a cost basis for certain explosive types and associated cost elements where deemed appropriate. These cases will be cited and commented on as to their reasonableness and depth of treatment.

The following subsections address each of the manufacturing cost elements considered in this study. The last subsection summarizes the estimates of the various elements of manufacturing cost.

Estimates of the current cost for each of the explosive product categories considered are shown in table .35, along with the raw material costs. The difference between price and raw material costs is made up primarily of labor, overhead, and markup (profit). Specific data for these important elements of cost were not available to this study, since this kind of data is considered extremely proprietary. The uncertainty in the specific division of the other costs and markups makes it difficult to assess the degree to which the explosives manufacturer will either absorb, or pass on through higher markups, the added cost of taggants in the manufacturing process. This issue will be amplified later.

Table 35.–Current Manufacturing Cost/Price Data

Explosive product category	Current cost of explosive raw materials [a]	Average current price per unnit
Cap-sensitive explosives.	15c/lb	50@/lb
Cast boosters	60cflb	$1.5011b
Black powder . .	11 c/lb	$6- $9/lbd
Smokeless powder.	NAc	$6 - $9/lbd
Detonating cord	2c/ft	5/ft
Blasting caps	20c - 30c/cap	50c/cap

‘Source I ME
bAerospace Corp
c The ME reference did not contain thiss data It IS known that the military Pays on the order of 88 cents/lb
d A leading manufacturer has recently quoted$9 of powder
SOURCE Officeof Technology Assessment

Revised Processes, Tooling, and Facility Costs

Cap-Sensitive Packaged Explosives

Requirements for additional tooling and equipment to accommodate the tagging process in dynamites, emulsions, slurries, and gels consist of equipment for weighing, hoppers, means of transferring taggant samples, and storage bins for secured storage areas. The cost for equipment to add the taggants into the explosive mixing process is small, as most manufacturers use a handmixing operation. Based on data provided by one explosives manufacturer, OTA estimated the added cost for these investments as a function of the unique batch size and other considerations regarding waste and productivity. OTA assumed a 10-year life, 10-percent interest rate in order to annualize this initial investment. Detailed requirements for other manufacturers of cap-sensitive packaged explosives were not made available for this study. OTA believes that these marginal cost requirements are representative of the cap-sensitive explosives industry.

The Aerospace Corp. indicated that some manufacturers might wish to install automatic taggant-dispensing equipment, and concluded that this cost should be similar to the cost of the labor it replaces and hence would be covered under the labor cost element. OTA'S study survey and site visits did not uncover any particular requirement for automatic dispensing equipment at either gel or dynamite manufacturing facilities.

Cast Boosters, Smokeless Powder, and Black Powder

Specific tooling and equipment requirements for these product categories were not available. For estimating purposes the assumption was made that the estimate for cap-sensitive explosives should be a representative value until detailed requirements are established.

Detonating Cord

Tooling designs must be developed in order to provide tagging capability at each detonating cord production line. Aerospace Corp. indicates that several pieces of hardware have been tested but no effective equipment is currently available. They further feel that a station configuration would apply both the identification and detection taggants together with an adhesive before the final assembly polyethylene sheath is applied, and that a reasonable cost for a station having a 5-year life is $50,000. Five such stations would be required by the industry for an annual production of 500 mill ion ft. The estimated cost for detonating cord tooling is **$250,000. Amortizing this cost over 5 years at 10-percent interest yields an annual cost of $66,000 or $0.00013/ft.**

Blasting Caps

The process by which taggants would be added to blasting caps has not yet been determined; it may well vary from one manufacturer to another. Alternate possible approaches are to place the taggants between two end plugs, embed the taggants within a single end plug, or add taggants to an existing interior polyethylene strip. Cost will vary considerably depending on the process chosen and the current cap assembly process. For purposes of the study, a conservative value of $2 million per manufacturer was assumed. Amortizing the $8 million cost (four manufacturers) over 5 years yields an annual cost of $2,112,000 or $0.025/cap. This figure would be high if one of the simpler methods of tagging detonators were adopted. However, the effect on the total cost of a tagging program is small.

Labor

Cap-Sensitive Packaged Explosives

Manpower estimates by the manufacturers indicated a range of requirements varying from two to six additional men at a site, The variation results from differences among particular site layouts, processes, and procedures in use, For instance, in one company effort would be required in various locations such as the dope house, works control, laboratory (including works laboratory), and in the magazine area. Additional activities involved include ordering, stocking, weighing, and supplying taggants to operators; collecting data, taggant samples, keeping records of codes; handling increased record keeping in magazine areas; and examining the codes before use in the manufacturing process. One contractor also indicated increased manpower costs due to code confusions and returned shipments. It should be noted that incremental labor costs for the actual mixing operation of taggants and related packaging are essentially zero. All additional estimated labor costs are associated with peripheral activities in coordinating, handling, and recordkeeping activities.

The estimate for labor, as indicated by the manufacturers, is Slightly greater than 1 cent/lb of explosives, which reflects approximately five to six additional men at the plantsite.

Cast Boosters

For the purposes of developing a baseline estimate, the Aerospace Corp. analysis is utilized here. Assuming that this will be a manual process, two additional personnel were estimated per assembly line, Given the four manufacturers (eight lines) the estimated annual cost is $400,000 or $0.067/lb of explosives.

Black Powder

Labor costs associated with tagging black powder were studied by the Goex Co. and referenced in the Aerospace Corp. Inflationary *y Cost Impact Study.* The estimated cost per pound of black powder for manufacturing labor of 1.5 cents is based on replacing the present date-shift code with a tagging material system. Elements include:

- storing tagging materials,
- security for storage and handling of tagging materials,
- administrative and recordkeeping, and
- impact on the manufacturing process (assuming a cleanup would be required in

the glaze and packhouse operation each shift).

This cost is exclusive of taggant material costs. Based on the study by Goex, OTA estimated the cost of labor for black powder to be 1.5 cents/lb.

Smokeless Powder

The Aerospace Corp. estimated labor effort added costs per pound of smokeless powder to be on the order of 6.6 cents (including the distribution system costs) and assumed that much of this cost could be absorbed within the current manufacturing and distribution organization. The estimate is based on the following assumptions:

- 2,000 lb/lot,
- 2,500 different tag lots produced, and
- 100,000 cases/year (50-lb cases).

Manufacturing costs were estimated to be 0.4 cents (of the total 6.6 cents). Since adequate data are unavailable to validate the estimate, OTA estimated the cost of manufacturing labor for smokeless powders at the same level as black powder, using the Goex estimate of 1.5 cents/lb.

Detonating Cord and Blasting Caps

The Aerospace Corp. estimate for detonating cord assumes that each assembly line would require one additional person to maintain a tagging station and to operate it during production. At $25,000 per man, the five stations would add an annual cost of $125,000 or $0.00025/f t of cord,

Similarly, the Aerospace Corp. estimates are used for blasting caps. Several additional workers may be necessary to operate and maintain the new equipment required. A reasonable estimate is four per manufacturer (there are four manufacturers) for an annual increase of $400,000. The resulting cost per blasting cap is $0.0048/cap.

Productivity y

Cap-Sensitive Packaged Explosives

Potential productivity losses have been estimated by the industry to be as high as 15 percent. The primary cause of such losses would be halting production to change taggant codes and avoid contamination. Consequently, the extent of such losses depends on the degree of taggant cross-contamination that would be permissible and the taggant batch size. Various kinds of cost can impact the situation. They are:

- **loss** associated with scraping of hoppers,
- new investment to offset production losses,
- loss of the market for mixed scrap, currently sold as an inexpensive explosive, and
- new investment for expanding waste disposal facilities.

As currently perceived by one major manufacturer of cap-sensitive packaged high explosives, productivity losses will have a direct cost impact in each of the areas noted above. Productivity losses are estimated at 15 percent in the condition where cross-contamination is not permitted and on the order of 8 percent where batch cross-contamination of 10 percent is permitted. Waste losses associated with scraping of hoppers every fourth mix were also estimated. A significant amount of the mixed scrap material is currently marketed as a low-quality explosive. If this material could no longer be marketed due to extensive taggant cross-contamination, there would be a further loss in profits. Current environmental regulations require that waste be disposed of by means other than burning in the open, in effect requiring additional waste disposal facilities. In order to maintain the current production and sales base, and thus maintain an adequate profit level for the company, additional production facility augmentation would be required to offset the expected losses in productivity.

The total cost due to losses in productivity could thus add up to several cents per pound of explosives for the worst case condition. If a 10-percent taggant cross-contamination level were permitted (BATF assumes this level) the cost impact would drop dramatically. If a special "composite code" were created, then tags containing this code could be added to scrap material and any other material containing cross-contamination in excess of 10 percent; investigators finding tags with the composite code would know that any other tags should be ignored, This would essentially eliminate costs for decreased productivity, The OTA baseline program assumes that such a composite code taggant is used, so that productivity losses are negligible.

Other Explosive Categories

Since pilot testing of adding taggant material to boosters, gunpowder, detonating cord, and caps has not taken place, the effects on productivity are not apparent. For purposes of costing the baseline system, OTA assumed there would be no productivity losses.

Inventory Costs

Inventory costs, including the associated cost of money, are a function of supply held in inventory. There is no reason to assume the tagged finished product would be held longer than is currently the case. It may be necessary, however, to stockpile a significant inventory of the taggant material to ensure an uninterrupted supply, particularly for identification taggants, where there is likely to be only one supplier. For the baseline case, the quite conservative assumtion was made that a 6-month inventory of both types of taggant materials would be stockpiled. The added costs for the various types of explosives would be:

('alp Cap sensitive	$0 0021'1 b
Boosters	$0 **0066/lb**
Smokeless powder	**$0 0021/1 b**
Black powder	**$0. 0021 lb**

Space and added labor have been included in the facility and labor costs detailed above. For the baseline case, no additional storage or labor would be required for cap-sensitive explosives, as the batch size would be the same as the current date-shift batch size. For the high-level program, with 10,000-lb maximum batch size, each batch would need to be separated by an access aisle from other batches, requiring additional space and labor. Access aisles would need to be maintained for inventory control and inspection.

Quality Control

Quality control cost estimates are included in the labor costs element. Some level of effort is required to ensure the taggant code and taggant quality prior to mixing. This effort would take place in the plant lab or "works" lab, to examine each code before use in the product. This appears to be a reasonable precaution since the integrity of all substances entering the "mix" must be assured to maintain prior safety levels. In addition, occasional specimens would be examined to assure that the taggant-mixing specification (uniformity, shelf-life, etc.) was being achieved.

Safety

Requalifying all product lines with taggant materials would be a necessary safety testing requirement for the various explosives manufacturers This one-time capital cost would involve analysis and testing of each type of product. To an extent uncertain at this time, the pilot testing programs have and will contribute to this requalification effort. Due to the uncertainty involved, OTA included the cost of safety requalification in the cost element estimates. It should be pointed out that the absolute cost levels of nonrecurring costs are not insignificant. However, after amortizing these costs over the significant production weights of explosive produced annually, the relative contribution of incremental costs to a pound of explosives is quite small.

Record keeping Costs

I n order to maintain the integrity of the identification taggant tracing network, a certain amount of additional or new recordkeeping must take place within the explosives distribution network. Current Federal requirements are that each explosive package and shipping case be marked with an identification code citing the:

- plant of manufacture,
- the date and shift manufactured, and
- the type and grade of explosives.

explosives covered under this regulation are the:

- cap-sensitive packaged explosives (dynamites, slurries, water gels, and emu ls ions),
- cast boosters,
- blasting caps,
- black powder, and
- detonating cord.

Records of the identification code must be maintained at the manufacturer level as well as each subsequent distributor. Smokeless powders are currently exempt from this requirement, although powders used to handload pistol ammunition must be recorded at the retail sales level.

The cost of recordkeeping has been included as part of the labor manufacturing cost elements.

Markup

To the extent that incremental taggant costs are passed on to distributors and users, markup costs must be included as part of the final product price. No specific data were available to treat markup for most of the explosive product categories. For purposes of establishing a baseline cost estimate, OTA assumed a IO-percent markup at the manufacturing level. This value may seem low, but all handling costs have been specifically covered in other cost elements, including an overhead allowance. Markup in that sense is essentially profit on the additional costs. Normal markups must cover al l of the handling costs.

In addition to manufacturing level markups, OTA considered the pyramid of markups that occurs throughout the various echelons of distributor and retailer levels. This is addressed in the next sect ion.

Summary of Manufacturing Costs Added

Manufacturing costs elements and total cost added as a result of the inclusion of identification and detection taggant materials in explosives are summarized in table 36. The added

Table 36.–Summary of Explosives and Gunpowder Manufacturing Costs included

Cost element	Costs included: Baseline case cap sensitive	Boosters	Black powder	Smokeless powder	Detonating cord	Blasting caps
Nonrecurring costs						
Tooling	Yes	Yes	Yes	Yes	Yes	Yes
Storage	No	No	No	No	No	No
Product requalification	Yes	Yes	Yes	Yes	NA[a]	NA[a]
Waste disposal facilities	No	No	No	No	No	No
New investment to offset product losses	No	No	No	No	No	No
Recurring costs						
Manufacturing process labor.						
Recordkeeping	Yes	Yes	Yes	Yes	Yes	Yes
Quality control. . . . . }						
Product losses.	No	No	No	No	No	No
Waste product line , .	No	No	No	No	No	No
Inventory costs	Yes	Yes	Yes	Yes	Yes	Yes
Administrative expense[b].						
Bottom line cost per unit of explosives	1.03/lb	7 7c/lb	2c./lb	7,2./lb	.04c/lb	3.lc/cap

[a]Data unavailable
[b]Included in labor

SOURCE Office of Technology Assessment

costs include the estimated costs to the manufacturer and associated markup as well as the markup placed on the cost of the taggant raw materials.

Manufacturing costs for cap-sensitive packaged high explosives are based on detailed inputs received from a major manufacturer. The raw data are proprietary informat ion and are not shown here. The detailed cost data were analyzed and alternative ground rules were established to gain insight into cost effects where taggant batch size was varied; related effects were taken into account regarding the productivity and waste issues. The cost elements included in various assumptions, along with the bottom line cost per- pound of explosives, are shown in table 37.

Table 37.–Cost Summary of Cap-Sensitive Packaged High Explosives Manufacturing Cost Variations With Assumptions

	Costs Included				
	Case 1	Case 2	Case 3	Case 4	Case 5
Cost elements	10000-12000 lb tag batch size	20,000-lb tag batch size	20,000-lb tag batch size plus allow cross-contamination	Tag batch size equals day s production	Plan! /year
Site manpower	Yes	Yes (less than case 1)	Yes (less than case 1)	No	No
Production losses	Yes	Yes	Yes	No	No
Waste	Yes	Yes (less than case 1)	No	No	No
Requalification	Yes	Yes	Yes	Yes	Yes
Waste disposal facilities	Yes	Yes (less than case 1)	No	No	No
Equipment and storage	Yes	Yes (less than case 1)	Yes (less than case 1)	Yes (less than case 3)	Yes less than case 3)
Investment to offset production losses	Yes	Yes (less than case 1)	Yes (less than case 2)	No	No
Taggant Inventory costs	Yes	Yes	Yes	Yes	Yes
Administrative	Yes	Yes	Yes	Yes	No
Bottom line cost per pound of explosives excluding markup	4.Oc/lb	2 3c/lb	1 4c/lb	O 6c/lb	O 3c/lb

SOURCE Office of Technology Assessment

DISTRIBUTOR COSTS

A general schematic illustration of the distribution network for explosives is shown in figure 15 while the network for gunpowder is shown i n figure 16 Detailed quantitative networks are not available; however, these illusstrations serve to depict the manner in which transactions take place within the industry. Within the networks, potential cost impacts occur in the areas of recordkeeping, processing and handling, storage, and further potential pyramiding of markup costs throughout the distribution network.

Recordkeeping at Distribution Levels

Record keeping and control of packaged high explosives are required by the present date-shift code regulation. Additional partitioning of explosive products may be required beyond that required by the date-shift code regulations, which may or may not have an incremental cost effect at the distribution level. NO detailed studies of additional recordkeeping elements which would be required, or the time necessary, have been conducted to date. I IME assessment of new activity requirements by the distributor includes.

- **comparing the taggant** lot numbers with the bill of lading with greater- frequency,
- classifying each explosiveproduct by typeby produ ct by t ype and taggant lot number to facilitate locating records,
- expanding **storage space** for the increaseci number- of books and records, and
- increasing the time to **locate** the proper product and taggdnt lot number at sale

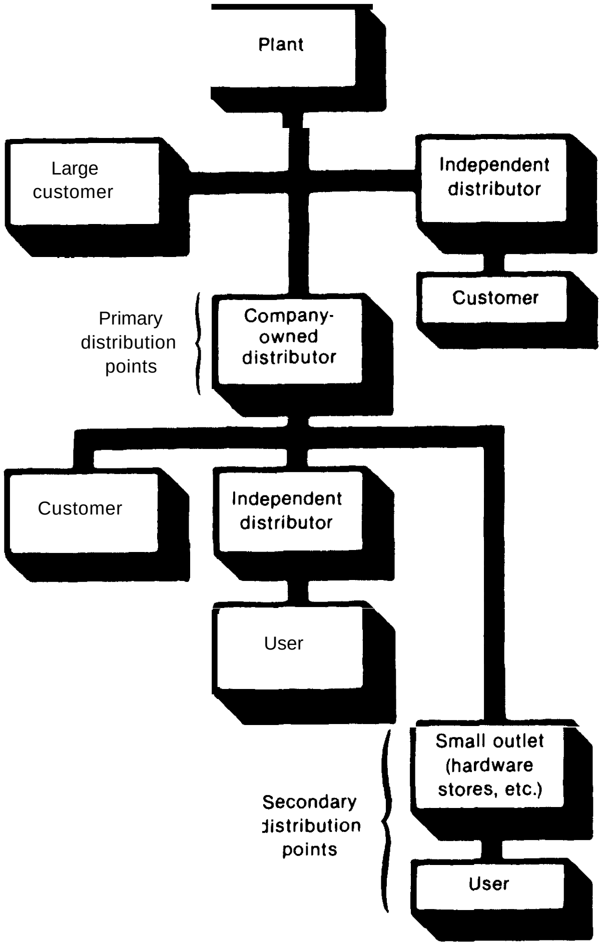
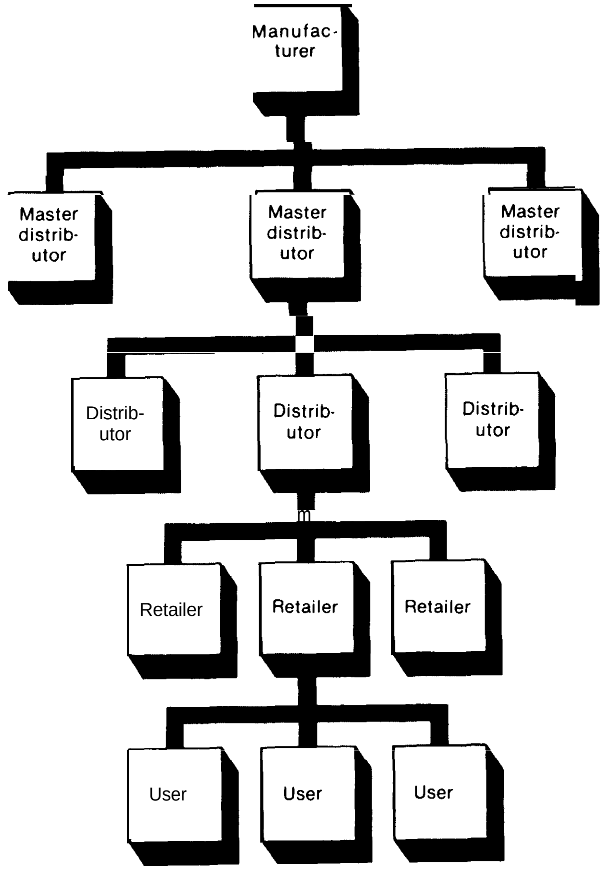


Figure 16.—Schematic Distribution Network of Gun powders



SOURCE: Office of Technology Assessment.

(due to the greater number of records that must be searched).

The Aerospace Corp. further considered:

- segregating material on trucks and in magazines to a smaller quantity; and
- recording additional information in orders, invoices, and inventory lists.

An analysis by the Aerospace Corp. of available BATF tracing records revealed that recordkeeping entries on bills of lading would involve:

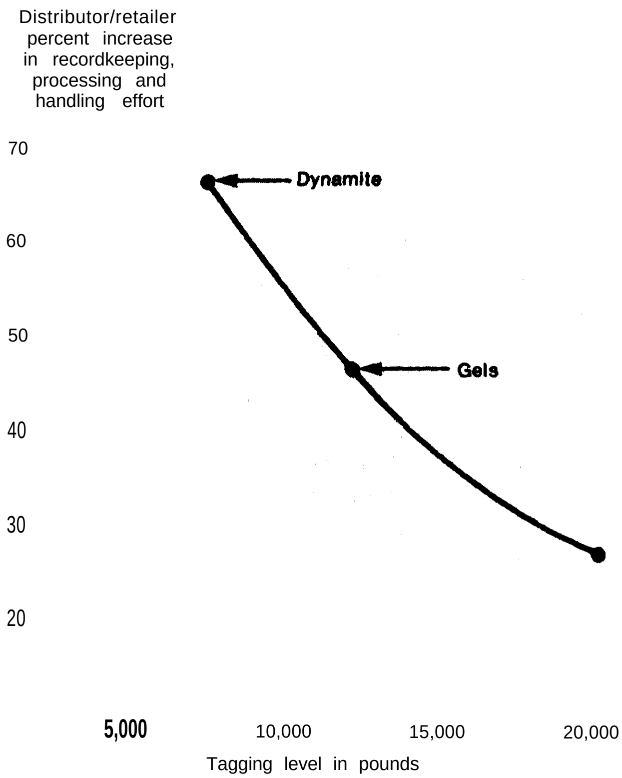
- 1.26 codes per order (20,000-lb tagging level) (based on 282 BATF traces of seven manufacturers in 1976 and 1979),
- 1.46 codes per order (12,000-lb tagging level) (based on Du Pont data), and
- 1.66 codes per order (7,900-lb tagging level) (based on dynamite traces).

In effect these data indicate that the additional recordkeeping, processing, and handling efforts for the finished explosives may be increased by up to 66 percent, depending on the tagging level. A plot of activity increases versus tagging level is plotted in figure 17. This plot underscores the dramatic inverse relationship of recordkeeping activity with the unique tagging batch level.

The Aerospace Corp. further reviewed the additional data entry requirements which

Figure 17.— Recordkeeping Activity v. Tagging Level

- **Cap.sensitive packaged explosives**
- **Impact on distributor/retailer**
- **Based on Aerospace analysis of BATF tracing record**



SOURCE Off Ice of Technology Assessment

would be required on bills of sale. Tagged explosive materials would require approximately 25 percent more entries than the untagged explosives for transactions at the distributor level. This analysis was specifically for tagging at the 20,000-lb level. At the retailer/explosive user level an 8.7-percent increase in data entries were computed using Federal form **4710 and the bill of sale or delivery ticket.**

Aerospace did not quantify the absolute cost impact as a result of this tracing analysis, but did conclude, however, that the costs would be insignificant for cap-sensitive packaged high explosives. The OTA analysis assumed that negligible added costs exist at the distributor retailer level for:

- cap-sensitive explosives,
- boosters,
- detonating cord, and
- blasting caps.

This conclusion is particularly appropriate for the baseline case, in which the taggant batch corresponds to the current date-shift code batch size.

The impact on the distributors of black and smokeless powders is somewhat different. Black powder and pistol-grade smokeless powder currently have significant recordkeeping requirements, while the other smokeless powder grades have no current recordkeeping requirements. (Pyrodex", a black powder substitute, would be marketed and regulated like smokeless powder, so incremental recordkeeping costs would approximate those of smokeless powder.) **An estimate was therefore made of the additional cost of entering the currently unregistered smokeless powder** in, and detailing it out of, the records at each distributor level by taggant code. It was assumed that a record for an "item" would take 2 minutes. The further conservative assumption was made that the average size of an "item" at the master distributor level was 25 lb (primarily case lots handled), was 10 lb at the distributor level, and was 2 lb at the retail level. Since considerable recordkeeping requirements currently exist for pistol-grade smokeless powder, the costs were assumed to be half those of the other powders. A small additional cost for recordkeeping was assumed at the retail level for black powder. The cents per pound added by those costs are shown in table 38.

Storage

Explosives are now generally separated by date-shift code batches for magazine storage at all levels in the distribution chain, as records must be kept, and physical control maintained by date-shift batch. For the baseline taggant case, no changes would be necessary. If the taggant batch were smaller, then additional storage space would be required for access. An estimate was made of the cost of magazine space, based on two data points. The added

Table 38.–Estimated Cost Impact for Powders at Distribution Network (cents per pound)a

Distribution level	Black powder	Smokeless powder: Pistol loading grade	Smokeless powder: Rifle and shotgun grade
Master distributors			
Recordkeeping . . . . .,	0	1 .2b	2.4C
Storage	0.2	0.2	0.2
Distributor/wholesale level			
Recordkeeping .	0	3d	6c
Storage	0.2	0.2	0.2
Retail level			
Recordkeeping.	1	I5e	30C
Storage ., . ., . .	0	0	0
	1,4	19,6	38.8

Total cost through the distribution chain
Black, . ., . . ., . . ., ., ... 1,4$
Pistol . . . ., .19,6$
Other. . . ~ . . . . 38.8$

If pistol powder is assumed to be 25 percent of total smokeless powder, the average cost impact for smokeless powder is 33c/lb.

aEstimate by Integrated master distributor wholesaler, retailer
bBased on I minute Average lot size 25 lb
cAssume 2 minutes/lot
dAssumed lot size IS 10 lb
eAssumed lot size IS 2 lb

SOURCE Off Ice of Technology Assessment

cost per pound of explosives was less than 0.1 cents, even for the case in which 10,000-lb maximum lots were tagged. For black and smokeless powders, the assumption was made that separation by taggant lot would require additional storage space at both the master distributor and distributor levels, but probably not at the retailer level. Using the same data base as above, the cost was estimated to be approximately 0.2 cent/lb at each level, as shown in table 38.

Summary Cost Including Markup

Distribution level costs are summarized in table 39. Markup on total costs incurred through the distribution system for explosives was assessed at 25 percent; for black and smokeless powders a total markup of 80 percent was assumed. This estimate is based on analysis of costs and price at each level, supplied by an integrated powder distributor. Table 39 sets forth the net cost added by the distribution network and further summarizes the net cost to explosive users from both manufacture and distribution **for the various** explosive categories. To illustrate the effect that the method of program implementation can have (taggant batch size and treatment of waste), costs for the five cases previously defined for the cap-sensitive high explosives are shown. Case 4 is, as noted, the OTA baseline case.

Table 39.–Distribution System-Summary of Cost Added and Markup (cents per pound)

Explosive category	Total cost leaving manufacturing facility	Distribution system cost added	Distribution system markup	Total cost added by distribution system	Total added price to user
Cap-sensitive packaged high explosivesv					
Case . .,	8.5	0.2	2.2	2,4	10,9
Case 2 .	66	0 1	1.7	1.8	8.4
Case 3 ., ...,	5.6	0.1	1.4	1.5	7.1
Case 4 (baseline). . . . ., . . .,	4.8	—	1,2	1,2	6.0
Case 5 ..., ..., . .	29	—	0.7	0.7	3.6
Boosters . . . ., ., . . .	20.9	0.2	5.3	5.5	26,4
Black powder,	6 3	1,4	6.20	7.6	13.9
Smokeless powder	6.3	33.0	31.4	64.4	70,7
Detonating cord ., .,	0.6	—	0.2	0,2	0.8
Blasting caps .,	5 0	—	1.2	1,2	6 2

SOURCE Office of Technology Assessment

USER COST IMPACTS

The cost increases estimated to occur as a result of the baseline taggant program are summarized and their impact on users analyzed.

Increased Material Costs

The net cost increase due to tagging explosives is summarized here. Summary cost impacts include:

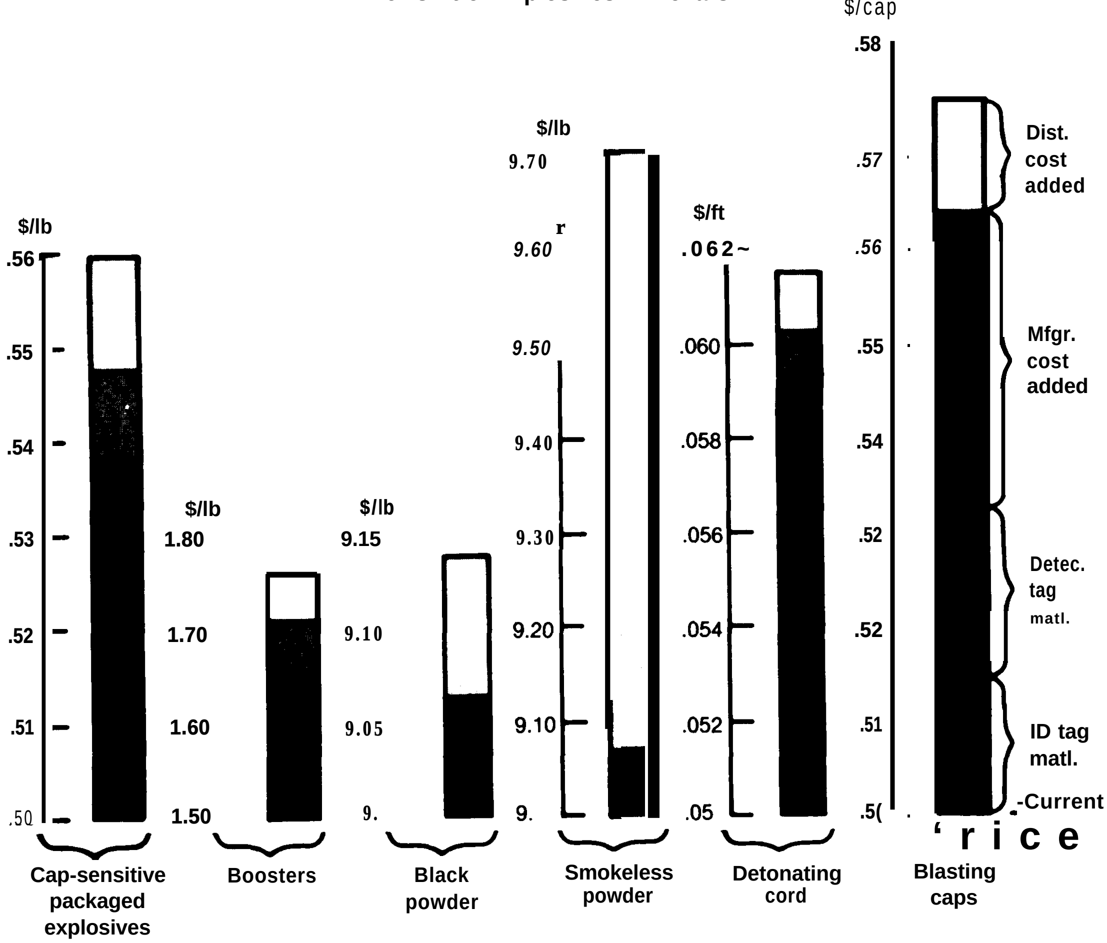
- the cost of identification taggant materials,
- the cost of detection taggant materials,
- manufacturing costs added including markup, and
- distribution network cost added including markup.

The following increases are noted for the baseline case:

Explosive category	*Percent cost increase*
Cap-sensitive packaged high explosives. ., ...	11.9
Boosters	
Black powder.	2.3
Smokeless powder	11.8
Detonating cord	.23.5
Blasting caps	15

The individual contributing cost elements to the overall cost impact are illustrated in figure 18 for the respective explosive categories.

Figure 18.—Summary of Added Costs to Explosive Users Cost Per Unit of Explosives in Dollars



SOURCE: Office of Technology Assessment

For the baseline case, the overall average increase in costs due to tagging is on the order of 12.8 percent, the weighted average for each of the above percentage contributions. The estimate of absolute annual cost increase in explosives is approximately $37 million.

Commercial Uses of Explosives and Gunpowders—General

Who uses commercial explosives and gunpowders? Over 55 percent of the total weight of explosives and blasting agents is utilized in the mining of coal, both in underground and surface mining operations. Quarrying and nonmetal mining are next in rank (1 5.4 percent) followed closely by metal mining (14.6 percent). Construction work at 10.6 percent and "other uses" at 4.2 percent complete the spectrum of user classes as adopted by BOM'S annual "Mineral Industrial Survey s." Onsite investigations were conducted for each of the major user classes in order to determine the order of magnitude cost and economic impact to the users of tagged high explosives. The selection of users investigated included both underground mining and surface mining as each type differs in the relative utilization of high explosives. Onsite investigations were conducted with the following users during the course of the study:

Underground mining
- Metal mining (copper) –Anaconda, The Crow Fork Mine, Utah
- Coal mine– Webster Coal Co., Kentucky.

Quarry
- Tri State, Maryland
- Rockville Crushed Stone, Maryland

Surface mining (open pit]
- Metal mining (copper)– Kennecott "Bingham Canyon Mine, " Utah

Construction work
- Guy F. Atkinson, California

The following sections describe the findings of the limited number of intensive investigations of the above explosive users,

Underground Mines

The Crow Fork (Anaconda) Mine near Toole, Utah, is a large, deep underground operation in hard-rock, mining for essentially high-grade ore. The mine will primarily produce copper, although significant amounts of silver, gold, and molybdenum are expected as byproducts. This mine is still under development and has had no production of ore as yet. Mine reserves are estimated at 20 years with an estimated production output capacity of 10,000 tons of ore per day. The total use of explosives is projected to be approximately **0.6** percent of total operating costs. Approximately 80 percent of the explosives used are non-cap-sensitive gels and blasting agents such as ANFO. The remaining 20 percent of explosives, including dynamites, slurries, boosters, detonators, and detonating cord would be subject to a tagging requirement if taggant legislation were enacted, A 12.8-percent boost in the cost of tagged explosives would translate into a 0.02-percent increase in the cost of mining, certainly an insignificant cost increase. The use of ANFO is currently related to clearing and aboveground excavation. Steady-state underground mining in the future can be expected to change the explosive mix and potentially increase the cost increase noted above. If all explosives used in the future were the cap-sensitive types, a taggant program would increase mining costs less than 0.1 percent.

The cost impact on underground coal mining is somewhat higher. At present, the cost of the cap-sensitive slurry and detonators (the explosives used to mine the coal) represents approximately 1.4 percent of the total cost of bringing the coal out of the ground. The increase in the cost of the explosives, due to tagging, would increase operating costs less than 0.2 percent. Other economic factors far outweigh increases of this sort.

Quarries

Discussion with the Rockville Crushed Stone Quarry revealed that explosives contribute to slightly over 8 percent of the gross total costs of operation. Between 1.5 million and 1.75 million lb of cap-sensitive (80 percent) and non-cap-sensitive (20 percent) explosives are utilized annually at their location. Since the environment is wet, no ANFO is currently utilized. The blasting activity is all contracted with a local blasting jobber, who provides the drilling, explosives, and blasting operation. The cost impact of an increase due to a tagging program is thus significantly higher in this explosive-intensive operation, However, the increase would still be less than 1 percent of operating costs. If the costs of explosives, caused by legislation of a tagging program, are much higher than estimated for the baseline program, then the quarry might investigate the cost potential of using inexpensive blasting agents, coupled with a water pumping operat ion.

A quite dissimilar situation is provided by the quarry operated by Tri State Explosives. The Tri State Quarry produces "facing stone" in various grades. The use of explosives in the operation is relatively insignificant, averaging from 10 to 15 blastings per year. Between 15 to 105 lb of explosives are used in each blasting, characterized as a "very precise operation. " The incremental cost of tagged explosives is therefore trivial.

Open Pit Mines

The OTA study team visited the Kennecott "Bingham Canyon Mine" near Salt Lake City, Utah. This open pit mine has many distinctions, including:

- the world's largest manmade excavation,
- the first open pit mine in the copper industry (started in 1904),
- the largest single mining operation ever undertaken, and
- the holder of the largest copper production record of any individual mine in history.

Figure 19 shows a photograph of the Bingham pit. Each vertical terrace is approximately 50 ft high. The mine is an extremely large user of explosives, with approximately 105,000 lb of explosives used per day or over 36 million lb/year. For every pound of explosives used, 4.2 tons of material are mined. Cap-insensitive explosives predominate the utilization, consisting of almost 80-percent ANFO and almost 20-percent cap-insensitive slurry. Explosive costs run from 3 to 5 percent of total operating costs. High explosives, although a small percentage of the total weight of explosives used, account for 7 to 10 percent of costs for all explosives used in the mine. Large amounts of primacord are used, together with boosters, detonators, and some dynamite for secondary blasting (e. g., breaking up boulders). High explosives therefore contribute on the order of 0.3 percent of the total cost of operation. The cost increase for a baseline taggant program would be on the order of 0.03 percent of operating costs.

Construction

The study team discussed the impact of tagged explosives with the Guy F. Atkinson Co. in South San Francisco, Cal if., a large contracting firm that utilizes large quantities of explosives in both underground (tunnels, etc.) and aboveground construction operations. In recent years this firm has utilized on the order of 20 million lb of explosives annually. In underground applications, operating costs are considered to be very sensitive to the cost of powder. Values placed on underground operations were:

	Pounds Of powder to remove yd ^{3}	*Cost per yd'*
General	**1/4** to- 1 3\4 lb	13 - **88**
Coal	**'/~ l b**	**17~**
Hard-rock	**1 lb**	50¢

In a recent tunnel application, Guy F. Atkinson used approximately 900,000 caps in the construction of a **22-mile** tunnel. At an estimated 50 cents/cap, the value of caps alone amounted to approximate y $500,000.

In aboveground work, Guy F. Atkinson recently utilized over 40 million lb of explosives in the construction of the Maloney Dam in California. This fixed-price contract was very

Figure 19.— Bingham Canyon Open Pit Copper Mine

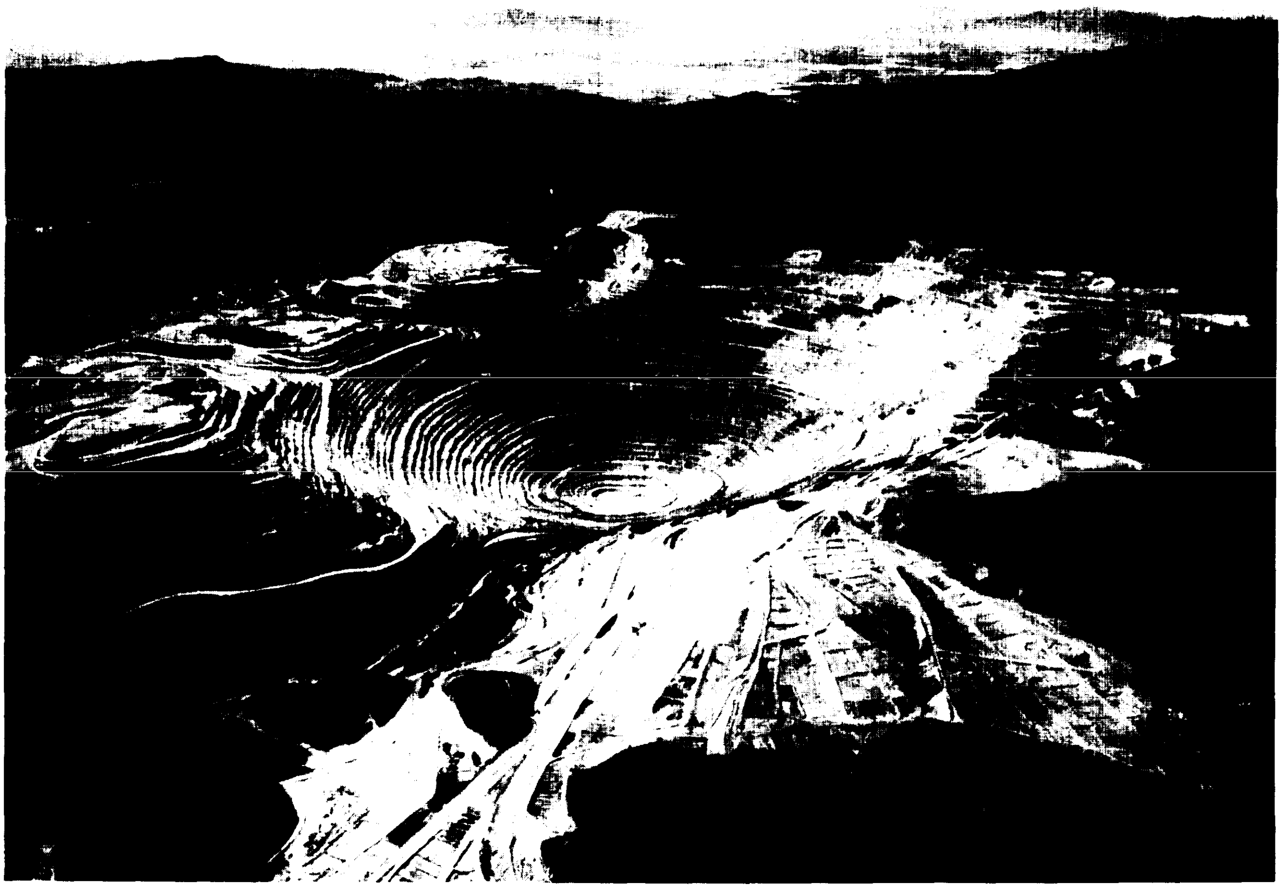


Photo credit: Kennecott Copper Co

"powder intensive." The value put on explosives was approximately 9 percent of operating costs, consisting of 70-percent cap-sensitive explosives and 30-percent ANFO.

A baseline taggant program would increase operating costs approximately 1 percent, a significant cost, but probably not sufficient to cause a shift to alternative excavation methods. One additional potential impact should be noted. Such construction projects are normally long-term, fixed-price contracts. A sharp jump in the cost of explosives during the course of the contract could significantly affect profits.

A summary of the findings on current explosive cost contributions to the various user classes is shown in table 40. Explosives percentage contributions to operating costs vary (dependent on user type) from less than 1 percent (underground metal mining) to as high as 9 percent (dam construction example). As a result, the cost impact of an increase in the price of cap-sensitive high explosives also varies, particularly as these explosives represent varying portions of the total explosive mix used.

Hand loading

The above cost impact calculations were for industries that are generally able to pass on increases in the cost of operations to their customers. Handloaders, however, are the ultimate users of the product, and must absorb

Table 40.–Current High Explosives Cost Impact for Various User Classes'

	Percent of operating costs	Percent Increase in operating costs due to baseline taggant program
Underground metal mining	0.2b	0.02
Underground coal mining	1.4C	02
Open pit metal mining	0.2 to 0.5d	003
Quarries	8 0[e]	10
Construction		
Aboveground dam construction	9.0[e]	10
Excavation–general	2 to 3	
Tunneling	5	—

[a]These are singlepoint samples
[b]Total Operating costs including refining were not available For direct mining cost operations explosives accounted for less than 1 percent of costs
[c]NOTE This data point reflects a highly efficient operation
'Excludes blasting agents
'Includes blasting agents

SOURCE Office of Technology Assessment

any increased cost due to a taggant program. Handloaders load their own ammunition for two reasons —economy and the hobby aspect. A less than 10-percent cost increase in expendable material is unlikely to affect a hobby for which hundreds of dollars in costs have already been incurred (hand loading equipment and guns). As powder is only one of several materials on which a hand loader saves costs (cartridge cases, projectiles, wadding) and additional cost-savings are realized from labor and avoiding paying the excise tax on purchased ammunition, an 8-percent increase in powder cost would translate into a very few percent increase in total reloading costs.

OTHER COST IMPACTS

Government Investigation Costs and Program Administration

BATF has estimated* a requirement of 11 man-years of effort annually to enforce the provisions of S.333, primarily to establish standards and monitor implementation of the taggants program. Estimated program costs in fiscal year 1979 dollars for this level of effort are approximately $500,000. This would include several explosive specialists, chemists, inspectors, and clerical help. Estimated costs for actually investigating taggant-tracing services are expected to be marginal beyond current BATF personnel levels and are contained in the above estimate. Their current tracing service personnel would require one additional slot at a cost of approximately $30,000. The total annual costs estimated for BATF are, therefore, just over $500,000.

Completing the spectrum of Government level costs are those expenditures that are budgeted and projected to complete the technical development of the taggants program by the Aerospace Corp. Total program costs (including sunk costs of $5.4 million prior to fiscal year 1980) are $10.0 million budgeted; projected outyear costs are estimated at $4.6 million.

*Atley Peterson's testimony, September 1977 on S. 2013

Investigative Costs

Investigators of bombing incidents currently devote considerable time to examining explosive debris for clues regarding the type and source of the explosive material. Further effort is devoted to forensic analysis at the laboratory level. If an identification taggant program is implemented, collection of debris for a laboratory search for taggants wil l become part of the standard bombing-scene investigatory procedures. There should be little or no impact on the time required for a bombing-scene investigation. Taggant recovery from the debris will be an additional laboratory exercise but it could we l l replace the more time-consuming procedures now carried out to obtain less information than would be furnished by taggants. Similarly, it will take time to follow up on the leads furnished to investigators by having a list of last legal purchasers of the bomb filler material, but that time is probably less than would be expended following up less direct leads. For purposes of this study, the assumption was made that a taggant program

would have no net cost effect on investigation time.

Effects of Competition-Substitution

Depending on the ultimate rise in the price of explosives to the user community due to the addition of taggants, a variety of economic impacts could occur. As has been pointed out earlier, the choices of the type of explosive purchased by users are frequently made on a basis of the lowest price rather than brand loyalty. Since this is so, various kinds of potential substitution threaten the explosives industry if the user perceives more economical choices available to him. For instance, in the underground mining of coal, the cost of explosives can play a predominant role in the overall cost of operations, particularly so in marginal types of mining operations. Substitution of mechanical coal mining equipment could essentially eliminate the use of explosives in those mines. The cost impact of the baseline taggant program is unlikely to significantly affect that type of choice, particularly given the capital investment in machinery that is currently used to support explosive mining. A full economic cost tradeoff analysis between mechanical tools and the increased cost of explosives would need to take place for a meaningful sample size of users to determine the net effect on the explosives industry.

Discussions with a dynamite and packaged slurry manufacturer revealed that in one case a recent 5.4-percent increase in the price of a slurry product resulted in several buyers shifting to other products—a loss in sales of **6** million lb of product for that manufacturer. Other estimated potential losses by substitution were suggested by the manufacturer. For instance, given a price increase of $1 0/1 00-weight in their nitroglycerine-based products, that manufacturer estimated that as much as 25 percent of their business would shift to other booster/slurry combinations. The manufacturer further estimated that if a 10-cent increase in the price of packaged slurries occurred, they could lose **50 percent of their slurry business to ANFO, as mining operations** would substitute borehole dewatering (by pumping the hole out and utilizing a borehole liner) coupled with ANFO. This kind of substitution, for cap-sensitive packaged high explosives to ANFO, was also noted by an explosives jobber (operating in a quarry environment) as a highly likely prospect should the cost of tagged explosives increase inordinately. I-he accuracy and objectivity of this type of unsubstantiated estimate are open to question, particularly as other operators expressed opposite views. Safety, reliability, and ease of handling were cited as reasons why a cost increase, such as would occur for the baseline tagging program, would not cause a product substitution. The examples do, however, highlight a very real potential problem, particularly if the taggant program were to substantially increase the cost of cap-sensitive explosives, or if a program were adopted that included tagging some portion of a cost-competitive segment of the industry (such as tagging dynamite, but not gels and slurries).

It is noted that the current annual utilization of ANFO in this country is on the order of 3.4 billion lb. It is estimated that the trend toward utilization of ANFO has gone about as far as it can go, given the excel lent economies for ANFO in a wide variety of circumstances. increasing inordinately the cost of explosives due to tagging could, however, further shift current utilization from cap-sensitive packaged explosives to ANFO.

Effects on Fixed-Price Commodities

There is a potentially important economic spillover on the marketplace for fixed-price commodities, due to taggants. Copper prices are established in a competitive worldwide market setting. The Kennicott copper mine, for instance, competes in this environment, and as a result is limited in its. ability to pass on additional costs of operations. Tagged explosives could affect this situation, depending on the degree of tagging implemented and the cost of tagging. The OTA analysis revealed that only insignificant influences on cost of operation would take place due to cost increases from a mandated taggant program. If ANFO and unpackaged slurries were also tagged, **however, the impact could be quite different.** The price of ANFO could approximately double, raising the cost of operations as much as percent. Such an increase may well require a higher grade cutoff point for ore, resulting in a significant decrease in the effective reserves of economically recoverable copper at that site.

Possible Removal of Some Gun powders From the Market

The initiation of a tagging program involves startup costs to the manufacturer, which this **analysis has assumed would be amortized over 10 years and passed along to the consumer in the form of somewhat higher prices. It is possible, however, that some manufacturers of black or smokeless powder might prefer to take some product lines off the market, so as to incur these startup costs for only a portion of their existing product line. It is also possible, though perhaps less likely,** that a manufacturer might choose to halt all production **for the handloader market rather than be involved in tagging** such powders. If this should occur, handloaders would find their existing choice among powders reduced; this reduction in choice would be a "cost" to handloaders, though not one which can be expressed in dollars.

TAGGANT PROGRAM COST SYNTHESIS

In this section of the report, cost estimates are established for implementing a baseline taggant program. This development of cost is an accumulation of total program cost elements developed in prior sections of the report. The program cost elements include:

- identification taggant material costs;
- detection taggant material costs; manufacturing level costs;
- distribution system costs; and
- public overhead costs:
  - — sensor-related production,
  - — sensor development,
  - — other taggant program development costs, and
  - — BATF annual administration and tracing activity,

Subsequent to the buildup of the total baseline taggant program costs, a series of alternative implementation levels are examined for their cost impact. Costs are estimated for a total taggant program and for separate identification and detection taggant programs. Following that are set forth the various aspects of cost uncertainty in the study and a cost-sensitivity analysis of key uncertainty cost drivers or parameters intrinsic to the taggant program.

Identification Taggant Program Material Costs

Table 41 shows the buildup of identification taggant material costs. The calculations, which are self-explanatory, are based on the program units (weight, feet, caps) set forth in the earlier section on "Taggant Material Costs, " A price for polyethylene encapsulated tags of $55/lb is utilized with the concentration noted. The total annual cost for this baseline condition is $11,200,000.

Detection Taggant Program Material Costs

Table 42 sets forth the buildup of detection taggant program material costs. The calcu la-

Table 41 .–Identification Taggant Material Annual Costs, Baseline Program

	Estimated annual production	Explosive average unit cost	Taggant concentration	Encapsulated/ unencapsulated (total pounds)	Taggant cost per pound	Increased cost per unit of explosives	Increase in explosive cost	Annual cost for taggant materials (dollars in thousands)
Cap-sensitive packaged high explosives.	325 million lb	$0.5011b	0 05%	Encapsulated (162,500)	$ 5 5	2.75u	5.5%	$8,900
Cast boosters, ., , .	6 million lb	$1 50/lb	0.1%	Encapsulated pellets (6,000)	122	12.2C	8.1 %	732
Smokeless powders	5 million lb	$6 00/lb	0,05%	Encapsulated (2,500)	55	2.75$	0 46%	137
Black powder,	400,000 lb	$9.00/ lb	0.05%	Encapsulated (200)	55	2.75c	0 30%	11
Detonating cord .,	500 million ft	5$/ft	5 taggants per inch	Encapsulated (160)	25/batch	0.05$	1 %0	250
Blasting caps .	84 million units	50c each	50 mg	Encapsulated (9,240)	120	1.32$ ea.	2 64%	1,100 (+46)[a]
Total program				. . .				$11,200

[a]Allowance for cap materials

SOURCE Office of Technology Assessment

Table 42.–Detection Taggant Material Annual Costs

Explosive category	Estimated annual production	Detection taggant level concentration	Detection taggant required, pounds	Taggant cost per unit explosives (@$40 /lb taggant)	Expected total annual costs (dollars in thousands)
Cap-sensitive packaged high explosives	325 million lb	0.025% by weight	87,500	1$	$3,250
Cast boosters	6 million lb	0.025% by weight	1,500	lc	60
Smokeless powders.	5 million lb	0.025% by weight	1,250	l	50
Black powder	400,000 lb	0.025% by weight	100	1$	4
Detonating cord	500 million ft	100 mg/ft	110,000	0.9C	4,500
Blastlng caps	84 million units	200 mg per cap worst case set	36,960	1.76c	1,478
Total . . .					$9,340

SOURCE Office of Technology Assessment

tions, which are self-explanatory, are established at the noted concentration levels and weights, feet, and unit quantities common to the identification taggant program. At the estimated cost of $40/lb of detection taggant material, the total annual program estimate is **$9,340,000.**

Manufacturing Level Program Costs

Explosive manufacturing level program costs are delineated in table 43. The annual cost estimate for the baseline program is $7,068,500. The costs are based on explosive quantities and manufacturing incremental costs developed in previous sections.

Distribution Network Program Costs

The annual program cost attributable to the distribution network is $9,231,000. The calculation, shown in table 44, is based on the quantities of explosives and distribution system incremental costs established in previous sec- t ions.

Public Overhead Program Cost

Public overhead program costs are defined to include the following cost elements:

- sensor-related deployment costs,
- taggant program development, and

Table 43.–Manufacturing Cost Added

Explosive category	Estimated annual producilon	Manufacturing cost added/unit	Total program manufacturing cost added (dollars m thousands)
Cap-senstive packaged high explosives .,	325 million lb	1.03[a]	$3,347
Boosters . .	6 million lb	7.72	463
Black powder	400,000 lb	2.57c	10
Smokeless powder	5 million lb	2.57c	128
Detonating cord .,	500 million ft	0.094C	470
Blasting caps .84	million units	3.15C	2,650
Total .,	.,	.,	**$7,068**

[a]Baseline condition

SOURCE Off Ice of Technology Assessment

Table 44.–Distribution System Cost Added

Explosive category	Estimated annual production	Distribution system cost added/unit	Total program distribution system cost added (dollars in thousands)
Cap-sensitive packaged high explosives .,	325 million lb	1. 19$a	$3,869
Boosters . .,	6 milllon lb	5.48	328
Black powder .,	**400,000 lb**	**7.55$**	**30**
Smokeless powder	5 milllon lb	6443$	3,222
Detonating cord .,	500 million ft	015$	750
Blasting caps .84	million units	1.23c	1.033
Total .,	.,	.,	$9,232

[a]Baseline conditions

SOURCE Office of Technology Assessment

- BATF administrative costs, including tracing activity.

The annual sensor program cost is $6.83 million for the baseline case in which 1,500 units are deployed in an assumed mix of 90-percent IMS and 10-percent MS sensor types. As indicated earlier, the annual BATF **administration** cost is approximately $0.53 million, while the taggant program development annual cost is estimated at $1.15 million, for a total of $8.51 million.

Taggant Program Baseline Cost Estimate

The total estimated cost for the baseline taggant program is $45.37 million per year. The calculation of this estimate is shown in table 45. It includes the estimated cost impact of

Table 45.–Taggant Program Summary Annual Cost-Baseline Program (millions of FY 1979 dollars)

	Annual cost
Taggant materials	$2056
Identification taggants(11 22)	
Detector taggants (9,34)	
Sensor-related costs a	683
Explosives manufacturers' added costs	7.07
Distributors' costs	923
Government costs. .,	1,68
Administration and tracing	
Taggant program development	
Increased Investigative costs .	0
Total baseline program annual cost	$4537

a Assumed 500 units 90.percent IMS and 10 percent MS

SOURCE Off Ice of Technology Assessment

taggant materials (identification and detection), manufacturer-added cost, distributor-added costs, and public overhead (sensors, taggant development, and BATF administration).

Program Cost Versus Implementation Level

Table 46 shows the major cost elements of the taggant program as a function of implementation level. The low-level program would use a unique identification taggant for each manufacturer, type of product, and year of

Table 46. --Taggant Program Summary Annual Cost Versus Implementation Level (millions of FY 1979 dollars per year)

Summary cost elements	Low case program	Baseline program	High case program
Taggant materials			
Identification taggants	$ 5.61a	$11.22	$1122
Detection taggants	934	934	934
Explosive manufacturers' added cost	5.26[b]	7. 07C	19.41d
Distribution system added cost	5.02[e]	9.23	16.55[f]
Public overhead	5329	8. 51[h]	24.5 ‘
Total program annual cost	$3055	$4537	$810 (less ANFO)
ANFO			*$187.0*
			$268.0

[a]OTA estimate of simplified code based on halving the baseline estimate
[b]Plant/year tagging level
[c]Date-shift tagging level
[d]10 00010 f 2 000-lb tagging level for cap-sensitive 2000 lb for powders
[e]Includes markup costs only
[f]Includes increase for adjusted markups 75 million lb of powders powder record keeping @ $1/lb
[g]Based on 800 sensors
‘Based on 1 500 sensors
[i]Based on 5 000 sensors
[j]Based on 34 billion lb of ANFO lagged annually ID lag @ 2¢/lb of ANFO detection lag c@ O 5¢/lb of ANFO manufacturing @ 2¢/lb of ANFO and recordkeeping @ 1¢/lb of ANFO

SOURCE Office of Technology Assessment

manufacture. A total of 800 detection sensors would be deployed, one for passengers and one for baggage at each airport location currently deploying magnetometers and hand baggage X-ray units. Cap-sensitive high explosives, detonators, boosters, detonating cord, and smokeless and black powders would be tagged with both identification and detection taggants. Blasting agents would not be directly tagged.

The baseline program would tag the same materials as the low-level program, but would use a unique identification taggant for each shift of each product — analogous to the current date-shift code marking on the exterior of explosives. Traceability to the lists of last legal purchasers would be maintained, as the taggant would contain all the information needed for a BATF trace (date, shift, product, and size). Approximately 1,500 detection taggant sensors would be deployed at airports and major controlled-access facilities such as powerplants, refineries, and Government buildings. Major police bomb squads would operate portable units.

This baseline program differs from the program proposed by the BATF/Aerospace Corp. team in two respects. The most important is that a full shift of the same product (a different size would be treated as a different product) would be tagged with the same taggant, rather than an arbitrary 10,000 to **20,000** lb. The practical utility result of that change is that a longer l ist of last legal purchasers would be produced by a trace, at least for those lines that make more than 10,000 to 20,000 lb of a product in a single shift. The second difference concerns rework. It has been assumed that a special taggant containing a "composite code" will be added to material containing more than 10-percent cross-contain inat ion; such a taggant would indicate that other codes in the explosive were contaminants and could be ignored.

The high-level program would uniquely tag each 1(),()0()-lb batch of explosive and each 2,000-lb batch of gunpowder. All explosive materials, including blasting agents, would be directly tagged. Ammonium nitrate fabricated for use in ANFO would be tagged, but not fertilizer-grade ammonium nitrate. Approximately 5,000 detection taggant sensors would be deployed at every major transportation facility, controlled-access utility, Government facility, and other potential high-value targets such as campus computer locations. Portable units would be routinely available to police bomb squads. The taggant level and types of explosives to be tagged in the high-level program correspond to a strict interpretation of S.333, as propounded by IME.

Program Cost of Separate Identification and Detection Taggant Programs

The above discussion has been for a program that includes both identification and detection taggants. Interest has been expressed in the cost of each program separately; the total cost and breakouts by cost elements are discussed for each of the three implementation levels. For the baseline set of conditions, the cost breakout is set forth in table 47. These costs are, in summary:

I dentification taggant program	$248 mlllon
Detection taggant program	$254 milllon
Total combined program	$4537 mlllon

Table 47.–identification Taggant and Detection Taggant Program Cost Comparisons–Baseline Case (millions of dollars per year)

Program cost elements	Identification taggant program	Detection taggant program	Baseline combined program
Taggant materials .,	,$1122	$9.34	$20.56
Sensor-related costs	–	6.83'	6.83'
Manufacturers' cost .,	6.0b	94 Markup 4.82 Labor and tooling	707
Distribution system cost,	6.66b	2.57 Markup -0- Labor and tooling	9.23
Government cost			
Administration and tracing	53	13C	53
Taggant program development	,34	81	1.15
Total ., ., ., .,	.$24.76	$25.44	$4537

[a]For 1,500 sensors
b LesS markup on detection taggant
CAssumed 25 percent of combined Program

SOURCE Off Ice of Technology Assessment

As one can note, the sum of individual programs is greater than the total combined program. This follows from the fact that each of the programs share certain labor and capital resources in the combined program and each opt ion bears the tota l cost for these resources if only one of the programs would be implemented. Shared resources in the combined baseline program are approximately $5 million/year, The detection taggant program is directly sensitive to the number of deployed sensors; variation in this would affect the cost differentials significantly.

Similar cost breakdowns were calculated for the separate identification and detector taggant programs at the low and high implementation levels; these separate costs for the three implementation levels are summarized in table **48.**

Table 48.–Summary Program Costs Versus Level of Implementation

	Identification	Detection	Total combined program [a]
Low	$ 1493	$2192	$3055
Baseline	2476	2544	4537
High	21454	6526	2688

[a]Combined program costs are less than the sum of the individual Programs because of shared labor tooling administration etc

SOURCE Office of Technology Assessment

Comparison of OTA Cost Estimates With I ME and Aerospace Corp. Estimates

In testimony before the Senate Governmental Affairs Committee, IME has estimated that the cost of the identification taggant program would be on the order of $700 million/year. That estimates includes the cost for the taggant materials, library maintenance fees, and record keeping costs. The estimate did not include public overhead cost, manufacturing added costs, costs through the distribute chain, and markup. In addition, the I ME estimates for the quantity of cap-sensitive explosives produced is lower than the OTA estimate by 50 million lb, IME does not include the effects of tagging 5 million lb of smokeless powder and assumes that the total production of **2.5** million lb of black powder would be tagged. All but 400,000 lb of the black powder is used as a raw material input to other manufactured items, such as fuzes, however, and so would not be tagged.

For a taggant program with the scope assumed by IME, OTA estimates the cost would be $214 million, not $700 million. The major reasons for this difference are: I ME assumed material cost for the identification taggants of $200/lb **(versus the** OTA estimate of $55/lb), the inclusion of a library maintenance fee of $100/-year per unique taggant (this fee would not be charged), and a concentration level of **0.05** percent for unencapsulated taggants versus the BAT F/Aerospace suggested level of **0.025** percent (equivalent to a 0.05-percent concentration level for encapsulated taggants). As indicated previously, the IME figures for the material and library maintenance costs reflect a 3M quoted cost for taggants produced in a pilot program.

Table 49 depicts the various cost elements for an identification taggant program that includes blasting agents. The three columns show, respectively, the element cost estimates made by I ME, the corresponding costs under the same assumptions made by OTA, and the actual cost elements, as estimated by OTA. It must be clearly understood that these cost esti-

Table 49.–Comparison of the Estimates for ID Tags (millions of dollars per year)

Cost elements	I ME cost estimate	OTA estimates using I ME assumptions[a]	OTA estimates using OTA assumtions
ID tag materials–non-ANFO	$ 525	*$* 1038	*$ 112*
ID tag materials–ANFO	3400	*68.0*	*680*
Manufacturers' costs–non-ANFO	—	172	18.47
Manufacturing cost–ANFO and recordkeeping	–	1020	102,0
Distribution system cost	–	8 0	13,98
Public overhead	–	87	87
Record keeping costs	195	in mfgr & distribution	in mfgr & distribution
Code reservation 291	1	—	—
Total	$703,1	$206.45	$21454

[a]Assumptions 275 million lb of cap sensitive packaged explosives 25 million lb of black powder smokeless powder not Included

SOURCE Office of Technology Assessment

mates are for the identification tagging program for the high implementation level.

The Aerospace Corp. cost estimate of approximately $48 million/year was for a different program—one in which ANFO and other blasting agents are not directly tagged. As noted above, the program for which the Aerospace Corp. cost estimate was given is quite similar to the OTA identified baseline program, differing only in the size of the unique taggant batch and in some assumptions on rework material.

A summary of major differences between the Aerospace Corp. assumptions and the OTA baseline case assumptions is as follows:

	Aerospace assumptions	*OTA assumptions*
Detonating cord. ...	12,000,000	500,000,000 ft
Number of sensors deployed .,	5,000	1,500
Increased investigating costs.	$5.4 million	None
Markup .,	No	Yes
ID tag material cost, encapsulated .	$50/lb tag	$55/lb tag
Detection tag material cost	$65/lb tag	$40/lb tag

Table 50 depicts the various cost elements for an identification and detection taggant program that does not include blasting agents. The columns represent, respectively, the cost estimates made by the Aerospace Corp. and the cost elements as estimated by OTA.

Table 50.–Comparison of OTA and Aerospace Program (Option 2) Estimate

Cost elements	Aerospace estimates	OTA estimate
ID tag materials ., ., .,	$8.58	*$11.22*
Detection tag materials	7.86	*9.34*
Labor	2.05	— b
Retooling. ., ., ., .,	1.65	— b
Total instrumentation cost	22.50	6.83
Increased investigative costs	5.40	-0-
Explosives manufacturing cost .,	(c)	7.07
Distribution system cost ., .,	(c)	9.23
Government costs, .,	—	1.68
Total ., ...,	*$48.04*	$4537

[a]From Explosives Tagging Inflation Impact Analysis Aerospace Corp April 1979
[b]Included in explosives manufacturing cost
[c]Included in labor cost

SOURCE Office of Technology Assessment

In **summary, the question as to which cost estimate is "correct," that by Aerospace or that by** IME, **cannot be simply answered, as they are giving estimates** for different levels of implemental ion. Both estimates contain values for cost elements that are not currently relevant, and these are clearly indicated in tables 49 and 50.

Who Bears the Cost of a Taggant Program?

For the baseline program set of conditions, an analysis was made to determine which of the various segments affected would bear the costs of the taggant program. Table 51 shows the cost breakout. Sensor-related costs would reflect the perceived utilization of sensors at airports for screening of personnel, hand-carried baggage, and checked baggage. For the baseline case of 1,500 sensors, 1,200 or 80 percent are assumed to be employed at airports, with **300** or 20 percent in Government buildings, courthouses, transportation centers, and police bomb squads.

The users of explosives absorb the primary impact of the program, assuming that all costs associated with the taggants (material, manufacturing, and distribution), are passed on to the various classes of users examined. The extent to which these costs will ultimately impact consumers of goods produced by the explosive users is uncertain.

Public overhead costs of administration and taggant program development are borne directly by the taxpayer who would also bear some portion of the detection taggant sensor deployment in the baseline case.

Table 51 .–Taggant Program Cost Impact by Who Will Bear the Cost (millions of dollars by impact segments)

Baseline program costs	Users of explosives	Taxpayers	Airline users	Total
Taggant materials . .	$20.56			$20.56
Sensor-related costs .,	–	$1–3	$5'53	6.83
Explosive manufacturers' costs	7,07	–	–	7.07
Ditribution system costs.	9.23	–	–	9.23
Public overhead	–	1,68	–	1.68
Total .,	$36.86	$2.98	$5.53	$45.37
Percent, . 81	,2%	6,6%	12 2%40	

SOURCE Off Ice of Technology Assessment

COST ANALYSIS PRECISION

In the preceding narrative description of the taggant program cost analysis, OTA has set forth the basis for estimating the various factors in the total program cost equation. The relative certainty (or precision) of the estimates has been addressed to varying degrees. In this section, OTA specifically summarizes concerns regarding the precision of the estimates and the related implications for: 1) the reasonableness of the estimates and 2) the prospects for cost-estimate growth or stability.

A precise evaluation of the costs of a taggant program is not possible due to the current state of development of the taggants and sensors and the uncertainties in how a taggant program would be implemented. Pilot testing has been conducted between the identification taggants and several of the types of explosive materials proposed to be tagged (cap-sensitive packaged explosives, boosters, and black powder), testing is underway on smokeless powder, and no pilot tests have been conducted for detonating cord or blasting caps. Three candidate sensors are being evaluated, but no system has progressed past the laboratory stage. Various implementation levels are possible, each of which directly affects costs. Examples of critical implementation decisions include: which explosives will be tagged, what would constitute a unique "batch" with a unique identification species, and how many of which type of detection sensors would be deployed.

Several forms of cost uncertainty analysis are possible. Given a baseline case, one can examine the cost effects of changes in individual cost factors and note the perturbation on total program cost in a deterministic manner. This method is employed in the following section in order to highlight the primary cost drivers in the taggant program. Another method treats costs in a probabilistic manner. Additional data would be required to implement this procedure.

Cost Sensitivity Analysis

The method used here essentially sets forth the cost impact changes that occur due to variations in cost-driving variables of interest. The cost-impact variations from an established or hypothesized baseline case is the traditional method taken. Cost element changes in absolute or percentage terms are set forth and the impact on total program cost is noted. Since the taggant program is in the early stages of development, the factors in the total cost equation need to be examined to determine the potential ranges of variance from an established baseline. Table 52 includes a relatively comprehensive list of elements that have an influence on the program cost estimate. These include the various factors (both cost and related requirements) for:

- taggant materials;
- the manufacturing and distribution system;
- public overhead (sensors, administration, taggant program development); and
- programmatic considerations.

Taggant Materials

IDENTIFICATION TAGGANTS

Various factors can further influence the cost of identification taggant material. The best estimate from 3M is based on their recent leadtime study, $75/lb of unencapsulated taggants in 2.5- to 5-lb lots. This value is based on tagging 600 million lb of explosives per year, requiring a guarantee of manufacturing of 150,000 lb of taggants per year for a minimum of 2 years. Values utilized in the OTA study are based on lower quantities of encapsulated taggants. 3M has made their best estimate of this effect on cost; however, more detailed study would be required by them to provide an equivalent confidence to the current $75/lb quotation. Encapsulated taggants estimates provided for this study are targeted at $55/lb of polyethylene-coated taggants for 90,000 lb of taggants per year. Additional study of opaque-

Table 52.–Elements of Cost Uncertainty

Identification taggant material
- Taggant cost dollars per pound
  - –Encapsulation cost-opaque capsule
  - –Yield from encapsulation process
  - –Cost is an estimate, not a contracted value
  - –Monopoly issue
- Taggant concentration level
- Quantity of explosives to be tagged
  - –Cap-sensitive packaged explosive
  - –ANFO and other blasting agents
- Taggant waste

Detection taggant material
- Molecule prices
- Encapsulation cost
- Concentration levels
- Quantity of explosives to be tagged

Sensor cost
- Quantity of sensors to be deployed
- What type sensors Will be successfully developed?
- What will be the mix of deployed sensors?
- Development cost uncertainty
- False alarm rate
- Production price uncertainty

Explosive manufacturers added cost
- Record keeping costs (particularly smokeless powders)
- Tooling and labor, etc . for explosive categories not pilot tested (powders, detonating cord, blasting caps)
- Batch size
  - –Productivity
  - –Waste
- Taggant inventory costs
- Markup and degree to which costs are passed on

Distribution costs
- Recordkeeping
- Storage
- Markup levels

Cost of investigation
- Cost penalty v. cost savings

Government regulation and administration

Implementation and programatic
- Level of Implementation
- Stand alone program costs
  - –Identification taggant program
  - –Detection taggant program

SOURCE Office of Technology Assessment

type encapsulation is required in order to refine the $55/lb estimate. 3M assessment of the worst case is $70/lb, to account for the uncertainty in:

- encapsulation and encapsulant ion process yield (further research is required to definitize these parameters), and
- ultimate contractual conditions specified (the only basis for "precise" quotations).

3M believes that the worst case estimate is highly unlikely and was provided to the study group to permit the cost uncertainty analysis of the taggant program. The ultimate effect of the worst case condition would be to increase identification taggant direct costs of materials by 27 percent.

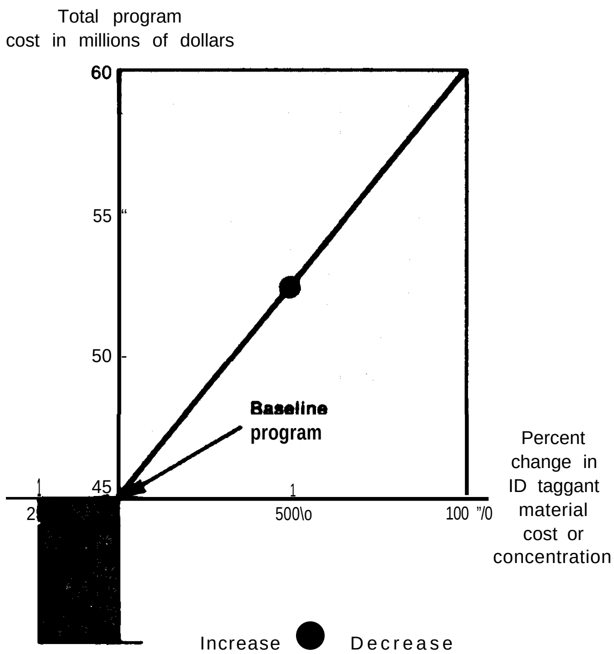
If one were to implement unencapsulated taggants, as was studied in some detail in the leadtime study, the ultimate effect would be a reduction in the baseline program estimate from $11.2 million to $9.6 million, a reduction of approximately 14 percent.

Other areas of cost uncertainty are:

- Monopoly issue–this is discussed in the second section of this chapter.
- Taggant concentration levels –the survivability and recovery tests so far conducted have been at one concentration level, as have the safety tests. The tests have identified areas where the taggants survive and areas where individual taggants do not survive (with a substantial grey area). Nonsurvival seems to be primarily a function of the thermal or physical decomposition of the taggant materials, which would be essentially unaffected by concentration level. If concentration levels were changed, the cost of material would increase almost linearly (see below).
- Quantity of explosives to be tagged–greater quantities (over 325 million lb of cap-sensitive) of tagged explosive would decrease cost per pound of taggant material; however, total program increases would not increase linearly.
- ANFO tagging—see the section on "Taggant Program Cost Synthesis" for estimated effects. It is probable that if ANFO were to be tagged, a taggant with additional layers would require development, to permit the larger number of codes required by the large quantities of ANFO and other blasting agents.
- Taggant waste— the degree of taggant waste (if any) in a production environment is unknown; this factor, which is not considered significant, would tend to increase taggant material cost estimates.

Summary baseline program cost sensitivity to variations in identification taggant material costs or concentration levels is depicted in figure 20. Cost-impact changes include the effect of markup at the manufacturing level and throughout the distribution network.

Figure 20.—Baseline Program Cost Sensitivity Impact With Changes in Identification Taggant, Material Cost, and Concentration Level



SOURCE: Off Ice of Technology Assessment

DETECTION TAGGANT MATERIALS

Detection taggant materials are still in the exploratory stage of development, with five candidate molecules currently under consideration. As shown in our discussion in the second section, estimates based on recent budgetary and pricing quotations vary depending on the molecule and the spread in the submitted cost estimates. The average value utilized in this study is $40/lb. The range of estimates is from $22 to $58/lb. The uncertainty in program dollar terms is as follows:

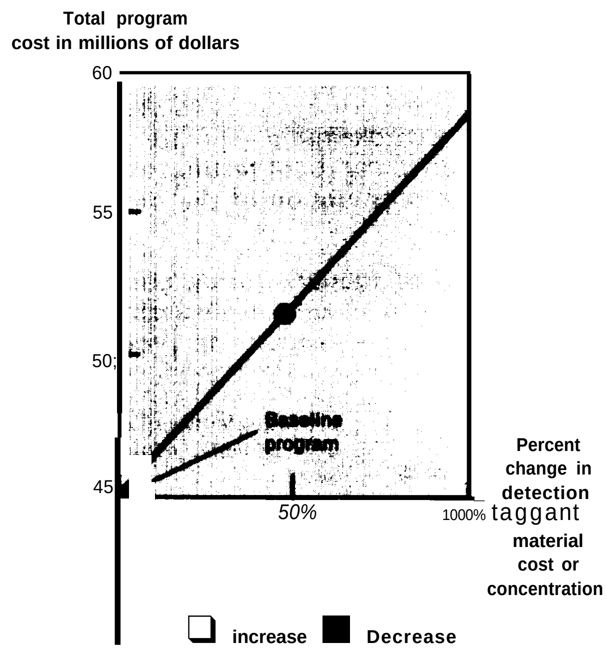
Baseline program	**$9.34 million**
Optimistic estimate ..	**$5.14 million**
Worst case estimate . . .	**$13.54 million**

Concentration levels are another issue. Current expectations are that 0.025-percent concentrations are adequate. Further development testing is required in order to definitive this parameter. Baseline program cost sensitivity due to a range of variation in detection taggant material costs or concentration levels is set forth in figure 21. Cost variations include the succession of markups that are estimated at the manufacturing level and throughout the distribution network. It should be noted that the concentration levels for identification and detection tagging of detonating cord are inconsistent, with a very small concentration of identification taggants assumed and a very high concentration of detection taggants.

THE MANUFACTURING AND DISTRIBUTION SYSTEM

Taggant program cost estimates at the manufacturing and distribution levels vary in their degree of precision and are highly influenced by various assumptions that are required due to the lack of substantive empirical data. Confidence is relatively higher in the estimates

Figure 21.—Baseline Program Cost Sensitivity Impact With Changes in Detection Taggant, Material Cost, and Concentration Level



SOURCE: Office of Technology Assessment.

where pilot testing has been accomplished (e.g., cap-sensitive packaged explosives). The degree to which costs will be passed on, with associated markups through the distribution network, to the user of explosives is another area of uncertainty.

As a result of the pilot test program, reasonable data is available for the analysis of the cost impact of adding taggants to the manufacture of cap-sensitive high explosives, at least for those companies that participated in the program. No similar data is available, however, on the manufacturing impact of the other types of explosive materials that might be tagged. Only gross estimates have been made for recordkeeping and storage costs.

Federal requirements for date-shift code recordkeeping currently pertain to cap-sensitive packaged explosives, boosters, black powder, detonating cord, and blasting caps. Smokeless powders, currently exempt from the requirement, represent the largest uncertainty in recordkeeping costs. OTA has treated this cost element parametrically with the level of implementation analysis. For the three cases studied, the following cost estimates were utilized:

Low program	no cost increase
Baseline	60.4/lb powder
High estimate	100$/lb powder

These estimates are based on preliminary assessments; further refinements in the smokeless powder recordkeeping estimate require a data base reflecting pilot-testing experience and a detailed description of the distribution network.

An analysis of manufacturing cost impact for cap-sensitive packaged explosives revealed the following cost sensitivity to program implementation levels:

Tag batch size	*Manufacturers' cost per pound of explosives*
10,000 to 12,000 lb	4.O
20,000 lb	2.3
Shift production	0.6$
Plant year	0.3

Uncertainty in other particular explosive type cost elements will persist until a particular program level is recommended for implementation.

Taggant inventory costs, which were assessed as part of the manufacturers' costs, were estimated at 10-percent interest for a taggant inventory supply of one-half year. Variations from this assumption would have relatively minor influence over total program cost effects. Markup costs were estimated at 10 percent at the manufacturing level and 25 percent for the distribution network for explosives, while 80-percent markup was utilized for the black and smokeless powders for the distribution network, based on estimated inputs from a manufacturer. Uncertainty exists in the degree to which taggant program costs will be passed on to explosive users, since ultimately these markups would be determined in the marketplace.

PUBLIC OVERHEAD

Sensor-related costs.— Considerable uncertainty exists in estimates of the sensor program cost. These relate to:

- what type of sensors will be successfully developed?
- what will be the mix of deployed sensors?
- how many will be deployed?
- development cost uncertainty,
- production price uncertainty, and
- false-alarm rates.

Table 53 delineates a set of cost possibilities where sensor mix and quantity are varied. One can note the wide spread of resulting estimates given these variations in assumptions. OTA estimated the sensor development costs of twice the level of the Aerospace estimates to ac-

Table 53.–Annual Cost per Sensor for Various Mixes

	Annual cost per sensor FY79 dollars	Total annual cost (millions of dollars) 1,500 sensors	5,000 sensors
All CECD	$3,318	$5.0	$16.6
All IMS	4,053	6.1	20.3
All MS	9,228	13.8	46.1
CECD 90% MS l0%.	3,909	586	19.5
CECD 75%; MS 25%.	4,796	72	24.0
IMS 90%, MS 10% (baseline).	4,570	6.8	22.8
IMS 75%; MS 25%.	5,347	80	26.74

SOURCE Off Ice of Technology Assessment

count for development program contingencies. Production cost estimates confidence has been stated by Aerospace as about * 25 percent. This production effect on the baseline case estimate would be as follows:

Baselne (1, 500 sensors).	$683 million
Low estimate	$512 million
Worst case	$854 million

The effects of quantity and sensor mix are more profound. Sensor costs could vary from $5 million to $13.8 million (see table 53) for the baseline quantity of 1,500 sensors depending on the ultimate mix of system deployed. Quantity variations would also proportionately impact program costs. High false-alarm rates (greater than 0.05 percent) in fielded sensors would have tangible cost impacts in the cost of operations and in creating ill will.

Programmatic considerations.— The overriding uncertainty in the cost of the taggants program stems from the nature of the present early phase of program development. Program cost uncertainty is a profound problem during the development phase of most major hardware system programs. This is so even for programs where precedent-type data are available (e.g., aircraft, missile, electronics). The taggant program has no direct precedent as such and analogous situations are limited. Historical data are therefore severely limited and slowly evolved as pilot testing progresses. Traditionally, as a program proceeds during development, new elements of costs are recognized that were poorly perceived at the onset of development" in addition, program directions change as ergineering and scientific problems are uncovered, resulting in scope changes and potential for cost growth. Questions of scope, for instance, include program implementation levels which have been addressed in the cost synthesis section. As noted, costs estimates can vary by significant degrees depending on the program specification. Related to the scope issue are the individual identification and detection taggant programs as separate entities. Pursuing either one of these objectives rather than proceeding jointly would have a significant impact on cost.

ADEQUACY OF CURRENT DATA

The taggant program cost estimates are based on a limited empirical data base and various analyses and assumptions. This situation is caused by the relatively early stage of the development program, the limited number of pilot tests conducted to date, and the limited sample of organizations surveyed (manufacturers, distributors, and users of explosives). The limitations in the data base and resultant assumptions have been underscored within the cost analysis section. Where assumptions were made, OTA has taken a conservative position in order to provide a reasonable cost estimate for the program options. This is important because cost growth normally ensues in typical developmental efforts. Cost growth is predominately affected by redesign and program scope changes; cost-es i mating error contributes to a lesser degree.

Further pilot testing and sensor deveiopment efforts are requi~ed in order to provide refined designs and requirements data for both manufacturing processes (e. g., detonating cord and blasting caps) and sensors, which are necessary for redefining the cost estimates. Until this progress is made, further refinements in cost-estimate precision are not possible.

Additional survey samples of manufacturers, distributors, and explosive users would provide higher confidence in certain of the cost-element estimates and other cost impact areas.

SUGGESTED FURTHER RESEARCH

Additional cost analysis research would improve the ability to determine more accurately and at a finer level of resolution the cost impact of the taggant program. This research effort could take a number of avenues including:

- development of a cost model,
- development of an economic model,
- application of design-to-cost principles for the sensor development, and
- special studies and analysis.

The **OTA study effort on the costs of the taggant program was limited** in time and resources. Various insights gained during this research indicate that further research in the above areas would contribute significantly to a better understanding of the multitude of cost and economic tradeoffs and effects which could guide the development of a taggant system. The model developments (cost and economic) would further this goal. Applications of formal design-to-cost principles to the development of sensors will further permit the production and implementation of cost-effective systems.

Other special studies and analyses would provide further value to the understanding of taggant program cost impact. Among these are:

- cost/uncertainty probability analysis;
- price elasticity for black powder, smokeless powders, and cap-sensitive high explosives, etc.;
- assessment of manufacturers' "front end" costs and the related burden; and
- amplified cost and economic impact surveys of manufacturers, distributors, and users of explosives.

It must be clearly understood, however, that resolution of the basic program issues, such as level of implementation, as well as resolution of technical efficacy, safety, and utility is necessary before it makes sense to attempt a more detailed cost analysis. The work reported in this chapter clearly indicates the order of magnitude of the cost impact that decisions concerning taggant legislation would have on the manufacturers, distributors, and users of explosives and gun powders.