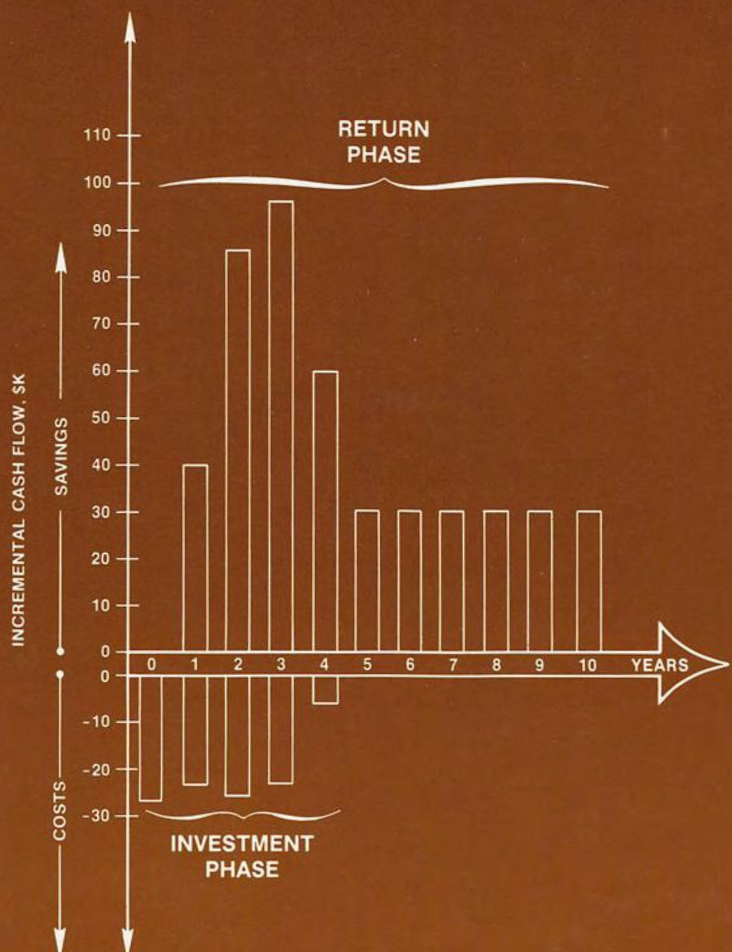
Application Note 222-3

A MANAGER'S GUIDE TO SIGNATURE ANALYSIS



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PACKARD

APPLICATION NOTE 222-3
A MANAGER'S GUIDE TO SIGNATURE ANALYSIS

An economic model for determining the cost/feasibility of adopting Signature Analysis in digital test and service.

FORWARD

ABOUT DIGITAL TROUBLESHOOTING

Microprocessors have revolutionized your product line. Your products are smarter, faster, friendlier and more competitive because they take advantage of μP-based control and computation. They are also harder to build, harder to test and harder to fix when they fail. Complex bus structures and timing relationships have practically obsoleted the scope/voltmeter signal tracing techniques so effective on analog products. The need to enhance the testability and serviceability of your digital products is acute. So is the need for specialized digital troubleshooting equipment.

ABOUT SIGNATURE ANALYSIS

To address these needs, Hewlett-Packard has developed the Signature Analysis technique, as well as a Signature Analyzer product line, for component-level troubleshooting of microprocessor-based products. A Signature Analyzer detects and displays the unique digital signatures associated with the data nodes in a circuit under test. By comparing these actual signatures to the correct ones, a troubleshooter can back-trace to a faulty node. By designing or retrofitting S.A. into digital products, a manufacturer can provide manufacturing test and field service procedures for component-level repair, without dependence on expensive board-exchange programs.

ABOUT THIS PUBLICATION

The management decision to adopt S.A. as a digital test/service strategy hinges on this question: Will expected cost reductions in final assembly and field service earn sufficient return on setup investment?

This Application Note advances an economic model for calculating comparative return on investment between different test/service strategies. It suggests simplified rules of thumb for estimating the costs, savings and feasibility of S.A. It concludes with ROI calculations for a sample product. The model is suitable for a wide range of digital products.

ABOUT OTHER PUBLICATIONS

Application Note 222-0, "An Index to Signature Analysis Publications", lists all other application notes currently available in the AN 222 series about Signature Analysis. They cover a wide range of interests, from how to design or retrofit Signature Analysis into digital systems, to the cost reductions that can be expected in production test and field service by doing so. It also lists all data sheets for the complete line of Hewlett-Packard Signature Analysis products, plus other related publications about digital troubleshooting.

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SECTION A—INTRODUCTION

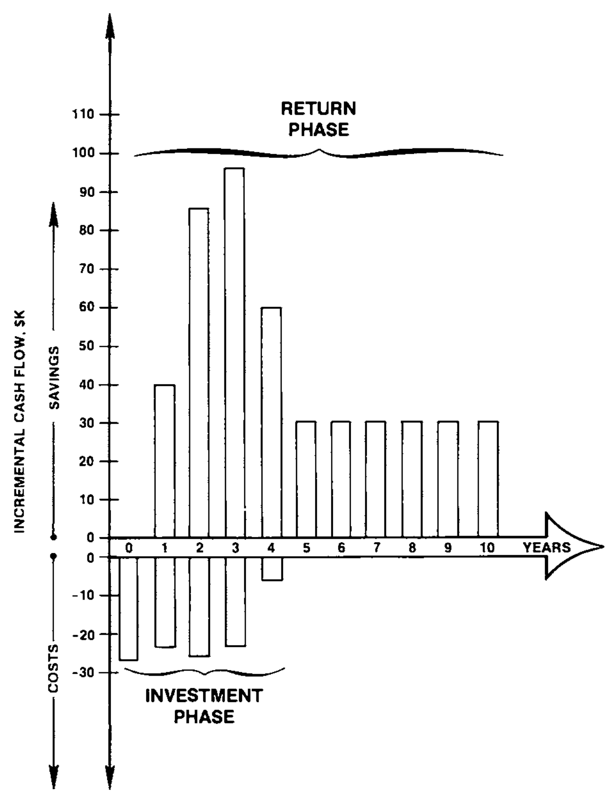
The costs of troubleshooting digital products in final assembly and field service are becoming increasingly visible, and are often perceived to be out of control. Strategies have been advanced which reduce these costs, but which also involve some initial investment in:

- Product Setup
- Test Equipment
- Documentation
- Materials
- Combinations of These Elements

For example, in order to implement Signature Analysis, [1] and take advantage of its savings in labor, processing and test equipment, a product usually needs to be set up, by design or retrofit, to utilize the technique. Therefore, the management decision to adopt or change a test/service strategy for a digital product hinges on the question:

> Will expected cost reductions in final assembly and field service earn sufficient return on the setup investment, and how do the returns for different strategies compare?

1. **Return on Investment.** The comparison of two digital test/service strategies can be considered a return on investment (ROI) exercise. The incremental costs of one strategy over the other are negative cash flows during the *investment* phase of the project. The incremental savings of that strategy are positive cash flows during the *return* phase of the project.



There are several common ROI calculations which allow comparisons of cash flows. This paper utilizes IRR (internal rate of return).

2. **Costs and Savings.** While the ROI calculation is straightforward, the estimation of the cash flows (costs and savings) is not. Existing costs are difficult to measure and proposed savings are difficult to predict. This paper attempts to simplify the exercise by offering some rules of thumb for cost/saving estimation. The rules are very conservative, resulting in higher costs and lower savings than our experience indicates. The effect is a tough comparison, assuring that adoption of a strategy will earn the target ROI.

3. **Model.** The model, then, consists not only of the ROI calculation, but also of a set of simple guidelines for cash flow estimation. It should allow comparison of alternatives in very short study times (one to two days), with minimum research. It is suitable for a wide range of digital products. All calculations are performed on a pocket calculator.

4. **Sample Product.** The paper presents the model via a sample product. The product represents a composite of our experience on hundreds of applications at Hewlett-Packard and other companies.

5. **Organization.** In order to help the reader apply the model to other products, the paper is organized as follows:

Section B — Initial assumptions on the sample product which affect outcome:
- Product Type
- Selling Price
- Cost Structure
- Production Life
- Service Life
- Number of Parts
- Forecast
- Field Failure Rate

Section C — Alternatives to be analyzed and their flow charts:
- Before (or current)
- After (or new)

Section D — Analysis of incremental costs:
- Engineering
- Documentation
- Test Equipment
- Component Stock
- Ongoing Materials

Section E — Analysis of incremental savings:
- Production Labor
- Warranty
- Field Service
- PC Board Stock

Section F — Return on Investment:
- Internal Rate of Return (IRR)
- Partial Implementation, Case 1
- Partial Implementation, Case 2

Section G — Conclusion:
- Summary of Results
- Cross references to tables and figures which allow another product to be studied.

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(1) This paper assumes some familiarity with the Signature Analysis technique. For a quick review, check one of the following Hewlett-Packard publications:
(a) Model 5004A Signature Analyzer Data Sheet. (02-5952-7464).
(b) Application Note 222, *A Designer's Guide to Signature Analysis.* (02-5952-7465).
(c) Application Note 222-2, *Application Articles on Signature Analysis.* (02-5952-7542).

SECTION B — INITIAL ASSUMPTIONS

In order to build a realistic economic model, we selected a sample product, and analyzed all of the cost and savings considerations for its digital test and service. So that the process may be applied to other products, this section details the assumptions we made concerning the sample product. It also discusses ways in which these assumptions may affect the results, if varied to accommodate other products. The section concludes with a summary table of the assumptions, with space to state assumptions for another product.

1. **Product Type.** We chose a relatively sophisticated graphic terminal as the sample product, because it incorporates a wide variety of digital troubleshooting challenges: microprocessor, ROM, dynamic RAM, keyboard, CRT controller, character generators, communication ports, etc. The analysis has been applied equally well to both simpler and more complex products.
2. **Selling Price.** The sample product sells for $5,000. The analysis has been used on products ranging from a $300 instrument to a $100,000 ATE system.
3. **Cost Structure.** Any analysis of cost savings depends heavily on the cost breakdown of the product. The larger an existing cost category is, the higher the impact of savings in that category on ROI. For the sample product, we estimated each cost element on the low side, in order to be conservative and lessen the impact of cost savings on ROI.

ELEMENT	COST
Direct Material	$1,000
Direct Labor	$ 250 (25 hours)
Factory Overhead	$ 750
Research and Development	$ 500
Marketing	$ 400
Sales and Service	$ 500
Warranty	$ 100
Other	$1,000

4. **Production Life.** The sample product has an estimated production life of four years. The longer the production life, the greater the impact of cost savings on the ROI model. However, the earlier years have the greatest impact on ROI.
5. **Service Life.** The time during which a product is supported in the field, after production is discontinued, depends on company policy. We assumed a ten-year service life. However, the length of this period has only a minor impact on the ROI calculation.
6. **Number of Parts.** The sample product has 315 IC's, distributed over 5 PC boards. The largest board has 150 IC's, the smallest has 20. There does not appear to be any upper limit on the number of IC's involved. However, it is difficult to show any savings on products of less than 5 IC's.
7. **Sales Forecast.** Assumption of an annual volume forecast over the product life is necessary in order to calculate production, service, and warranty costs and savings. The sample product uses this forecast:

YEAR	QTY SHIPPED	$ VOLUME	SERVICE BASE	WARRANTY BASE
0	0	0	0	0
1	600	$3M	600	600
2	1200	$6M	1800	1200
3	1200	$6M	3000	1200
4	600	$3M	3600	600
5-10	0	0	3600	0

The analysis has been used on products with both higher and lower volumes.

8. **Field Failure Rate.** We assumed a yearly failure rate of 10% of the total installed base for the 10-year service life of the sample product. This is conservatively low, since the higher the failure rate, the greater the savings which can be realized in cutting service costs.

YEAR	FAILURES	IN WARRANTY	OUT OF WARRANTY
0	0	0	0
1	60	60	0
2	180	120	60
3	300	120	180
4	360	60	300
5-10	360	0	360

SUMMARY OF MODEL ASSUMPTIONS

Item	Sample Product	Product Under Study
1. Product Type	Terminal	
2. Selling Price	$5,000	
3. Cost Structure		
Material	$1,000	
Labor	250	
Overhead	750	
R&D	500	
Marketing	400	
Sales/Service	500	
Warranty	100	
Other	1,000	
4. Production Life	4 Years	
5. Service Life	10 Years	
6. Number of Parts		
Boards	5	
IC's	315	
7. Forecast		
Year 1	600 units	
Year 2	1200 units	
Year 3	1200 units	
Year 4	600 units	
8. Field Failure Rate	10% Per Year	

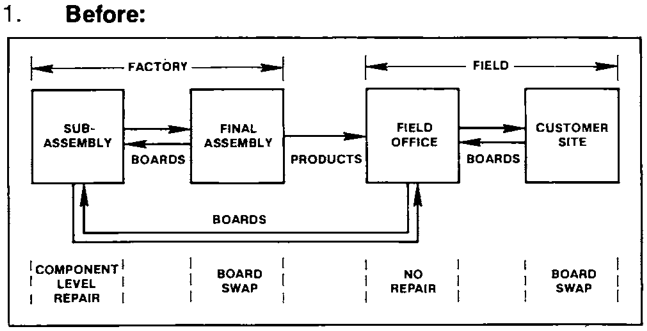
SECTION C — ALTERNATIVES TO BE ANALYZED

The analysis may be used to generate the incremental ROI between any two alternative digital test and service strategies. We chose to compare two strategies which meet these criteria:

1. **Before:** The most common strategy now used by companies with digital products.
2. **After:** The simplest, first-step improvement over the current strategy.

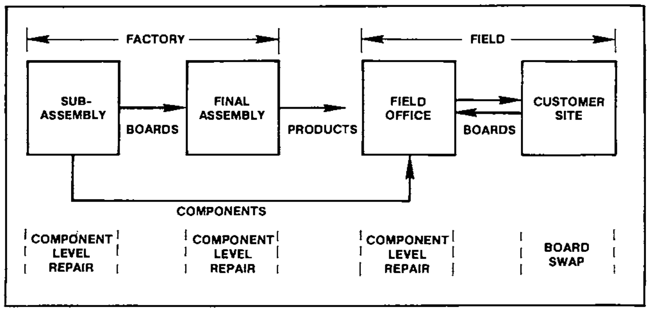
Here is an outline of each of the alternatives studied.

1. **Before:**



This alternative represents the most common strategy for digital test and service. Products which fail in the final assembly area (turn-on, heat-run, final test, QA, etc.) are repaired by swapping PC boards. Bad boards are returned to a subassembly test area for component level troubleshooting and repair. Products which fail in the field are repaired by swapping PC boards at the installation site. Bad boards are returned to the subassembly test area, via the field office, for component level troubleshooting and repair.

2. **After:**

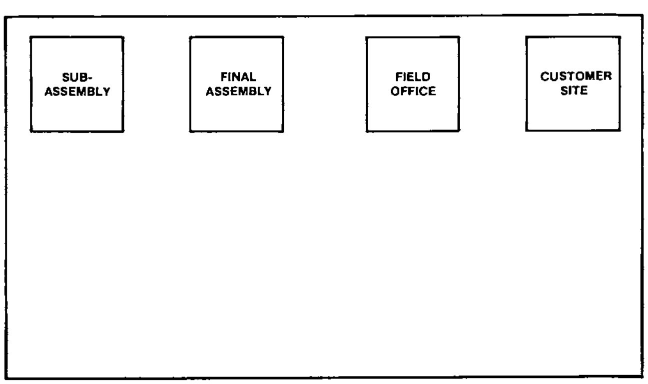


This alternative represents a strategy which could be implemented by setting up the product to be repaired to the component level. Products which fail in the final assembly area are troubleshot and repaired to the component level, without disassembly. Products which fail in the field are repaired by swapping PC boards at the installation site. Bad boards are returned to the field office for component level troubleshooting and repair. No boards return to the factory. We implemented this strategy on the sample product by incorporating the Signature Analysis technique. This required some incremental expenses, over and above what we would have spent to set up the product for straight board-swap repair. However, the savings in repair labor, materials and handling yielded a very attractive ROI. Expenses and savings are detailed in the following sections.

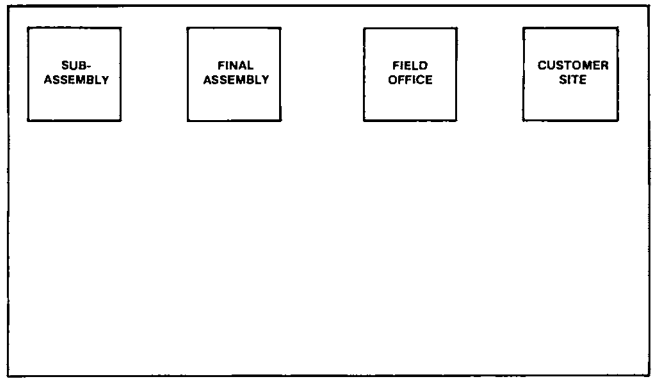
Note: This alternative specified board-swap repair on-site. Additional savings could be generated, with no additional costs, by repairing products on-site, to the component level. There are many examples of this. However, we chose not to take advantage of these savings in the model, since many installation sites are not suitable for replacing components on boards.

3. **Product Under Study.** Here is some space to model comparative test/service strategies for another product.

Before:



After:



Note: Just fill in the appropriate product flows to describe each strategy.

SECTION D — ANALYSIS OF INCREMENTAL COSTS

In order to implement the new strategy for digital test and service in the sample product, we incurred some incremental costs, compared to those for the current strategy:

1. Engineering
2. Documentation
3. Test Equipment
4. Component Stock
5. Ongoing Materials

Here is a detailed analysis of each of the incremental cost areas. The results are summarized at the end of the section, and space is provided to analyze incremental costs for another product.

1. **Engineering**

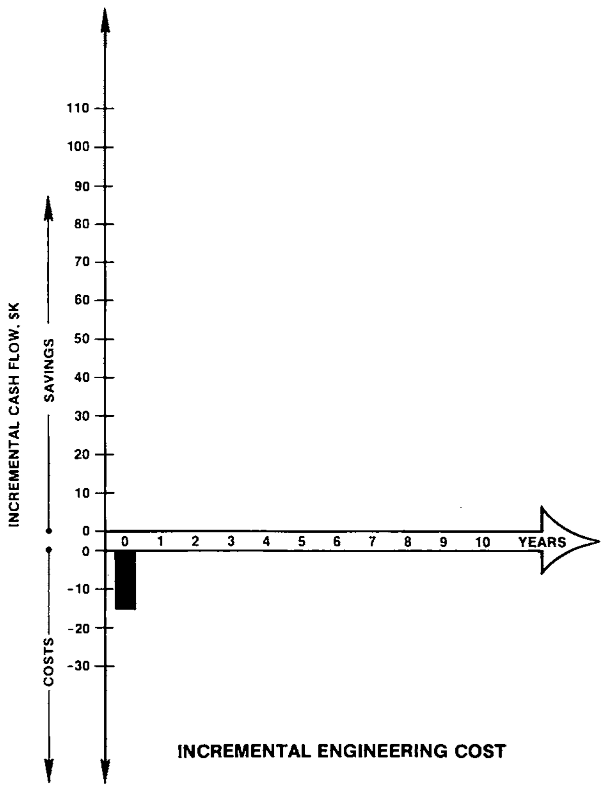
a. **Description.** In order to set up a product to be repaired to the component level with Signature Analysis, some engineering time is required. The time is devoted to minor hardware re-layout and software modification. If implemented in the design phase, the design team handles it. If implemented as a retrofit, the time generally is spent in the manufacturing engineering area.

b. **General Rule.** A good, conservative rule is to use 1% incremental engineering time.

c. **Actual Experience.** We have reported estimates of 1-4 man-weeks of incremental engineering time. This rarely amounts to 1% of the entire design project. The time appears to be the same, whether spent in design or in retrofit. However, there is room for reporting error here, since these are estimates.

d. **Sample Product.** This product required the equivalent of 5 engineers (all types) for 3 years of design. This is 180 man-months, total. Of this, assume that 2 man-months (1%) were devoted to setting up the product for component-level repair. We used a conservatively high figure of $7,500 per month for fully loaded design time, for a total incremental cost of $15,000.

e. **Timing.** The engineering time is spent at the end of the design cycle, just before production. We show it in year 0.



INCREMENTAL ENGINEERING COST

2. **Documentation**

a. **Description.** Troubleshooting procedures are more thorough for component level repair, than for board-swap. Signature Analysis greatly reduces the burden; however, there is some incremental time involved:

- gathering signatures.
- writing procedures.
- verifying both.

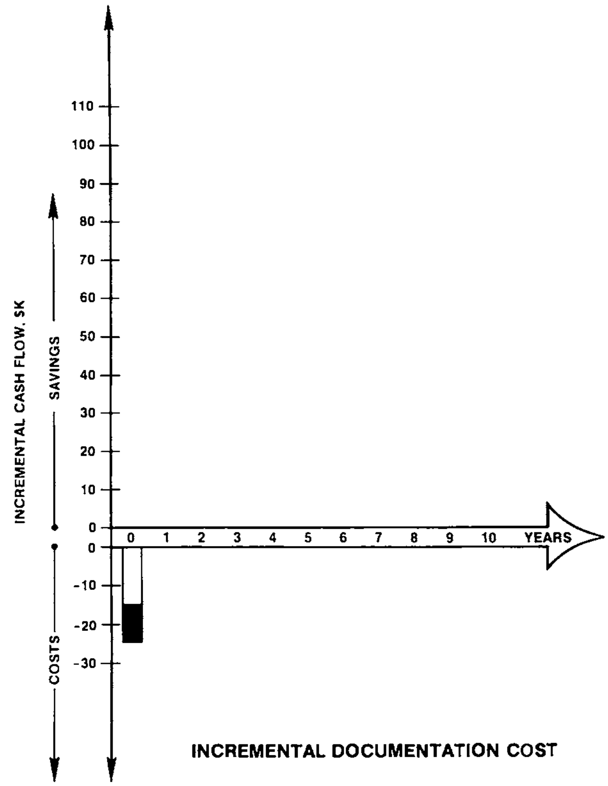
The time is spent in product support engineering, manufacturing test engineering or service engineering.

b. **General Rule.** A good, conservative guideline is to use 2 man-months for incremental documentation time.

c. **Actual Experience.** We have reported estimates of 2-4 man-weeks of incremental documentation time, so the general rule is quite conservative. Remember that this is only the incremental time spent to add Signature Analysis instructions to the procedures which would have been prepared under the current strategy.

d. **Sample Product.** Two man-months of documentation effort were targeted at a loaded cost of $5,000 per month, for a total incremental cost of $10,000.

e. **Timing.** The documentation time is spent in the pre-production and early production life of the product. We show it in year 0.



INCREMENTAL DOCUMENTATION COST

3. **Test Equipment**

a. **Description.** Utilizing the Signature Analysis technique requires purchase of Signature Analyzers, at $1,000 each, in these locations:

(1) Lab — for aiding in the design or retrofit of Signature Analysis into the product.

(2) Service or Test Engineering — for documenting the troubleshooting procedure.

(3) Production — for troubleshooting in the final assembly area.

(4) Field Offices — for field service troubleshooting of returned boards.

b. **General Rule.** Plan on one Signature Analyzer for the lab for design, and one for service/test engineering for documentation. In the final assembly area, plan on one unit per test position or, if the unit can be shared, one per 3 final test technicians. In the field, plan on one unit per office, initially. (The upper limit for field service will vary. One guideline is to put one unit in the field for each field service technician. Another guideline would be to put one unit into each field office for each 50 projected repairs per year.) Each Signature Analyzer, of course, is usable on any future products which utilize the same technique.

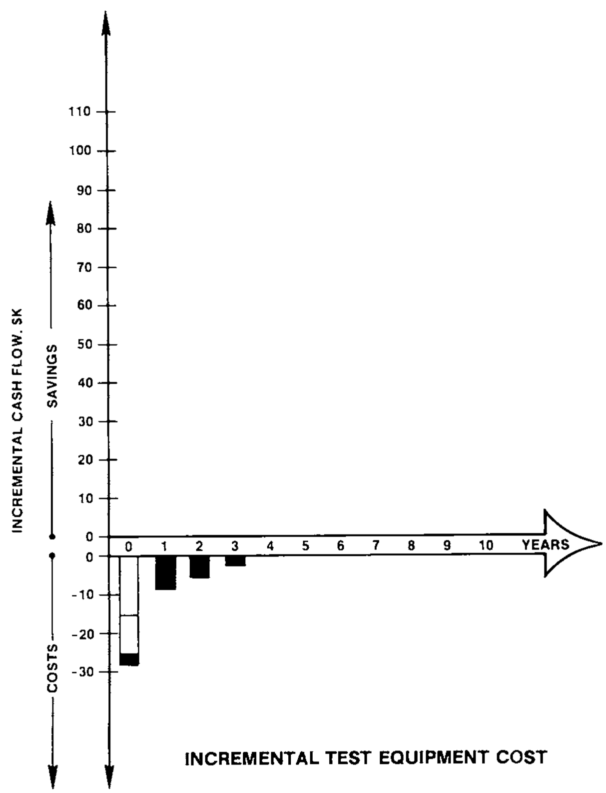
c. **Actual Experience.** Individual companies have implemented component-level repair programs, utilizing Signature Analysis, with from 5 to 400 Signature Analyzers. We find the general rules, above, conservatively high.

d. **Sample Product.** For the sample product, we used one Signature Analyzer each, in design and service/test engineering. We used 5 units to cover 10-12 final test technicians in production, and used 10 units to cover the five offices for field service. The total was 17 units, or $17,000.

e. **Timing.** These 17 Signature Analyzers were acquired over 4 years, as shown.

INCREMENTAL SIGNATURE ANALYZER COST

		YEARS					
LOCATION	**UNITS**	**0**	**1**	**2**	**3**	**4**	**5-10**
Lab	1	1	0	0	0	0	0
Service/Test Engineering	1	1	0	0	0	0	0
Production	5	0	3	2	0	0	0
Field Service	10	0	5	3	2	0	0
Total Units	17	2	8	5	2	0	0
Cost @ $1,000	$17,000	$2,000	$8,000	$5,000	$2,000	0	0



INCREMENTAL TEST EQUIPMENT COST

4. **Component Stock**

a. **Description.** Since the new strategy calls for component-level repair in field offices, we require parts kits, which would not have been stocked currently. These are startup parts kits, which are added during the life of the product, as required by the growing installed base. We do not show factory parts stock here, since it is approximately the same under either strategy.

b. **General Rule.** Itemize one of each IC per kit. Plan on enough kits to handle 2 months' failures, at the predicted mature failure rate. This is very conservative, since successive failures rarely require the same part at the same location.

c. **Actual Experience.** Most service groups have found that they do not require all electronic parts to be in a kit, and that they can understock multiple usage parts. Actual stocking requirements come in well under the general rule.

d. **Sample Product.** The sample product has 315 IC's (Section B-6), the costs of which are:

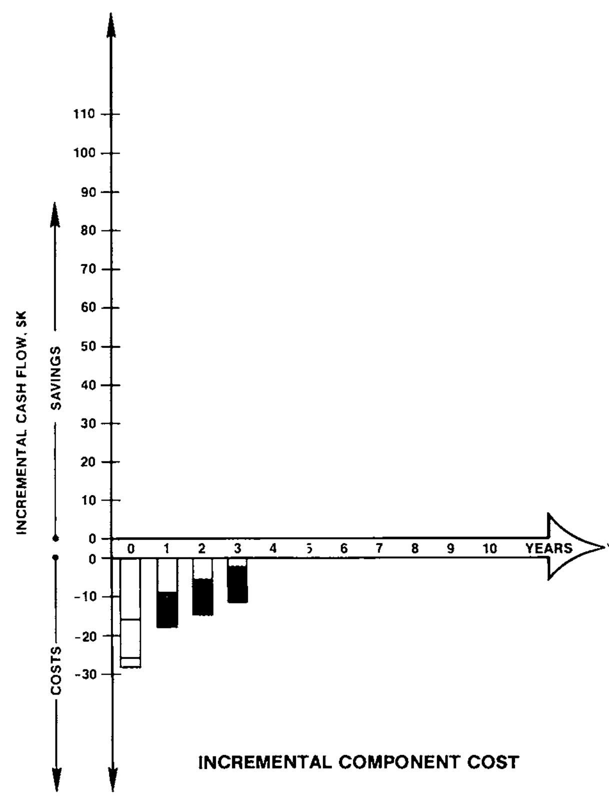
300 IC's at $1.00 each	=	$300.00
15 IC's at $10.00 each	=	$150.00
Total cost per kit		$450.00

The mature failure rate was projected at 30 per month (Section B-8), so two months' failures are covered by 60 kits, or $27,000.

e. **Timing.** We acquire the 60 kits over a period of 3 years, keeping well ahead of the projected installed base, as follows:

INCREMENTAL COMPONENT COST

		YEARS					
	QTY REQUIRED	**0**	**1**	**2**	**3**	**4**	**5-10**
Field Parts Kits	60	0	20	20	20	0	0
Kit Costs at $450.00	$27,000	0	$9,000	$9,000	$9,000	0	0



INCREMENTAL COMPONENT COST

5. **Ongoing Materials**

a. **Description.** When setting up a product for Signature Analysis troubleshooting, there are generally some additional parts required in the product itself. These usually consist of switches, jumpers, test points, a socket, etc. (Active components are rarely required.) These parts then contribute to a small incremental material cost.

b. **General Rule.** Add 1% of the standard material cost.

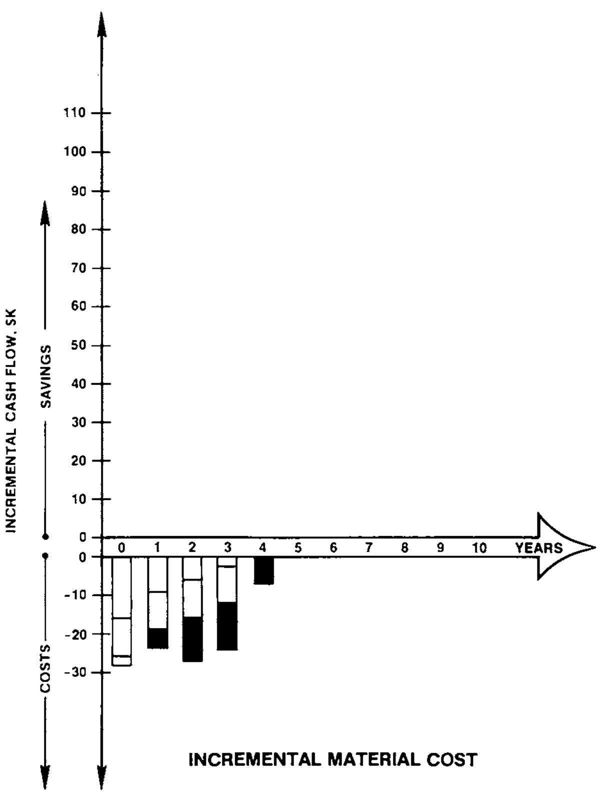
c. **Actual Experience.** Incremental material costs (assuming no additional ROM space is required) range from 0-$5.00 per unit.

d. **Sample Product.** Using the 1% rule on the $1,000 material cost (Section B-3), we have a conservatively high incremental material cost of $10.00 per unit. This is then applied to the forecast (Section B-7) to obtain the annual incremental cost.

e. **Timing.** Material costs are incurred as follows:

INCREMENTAL MATERIAL COST

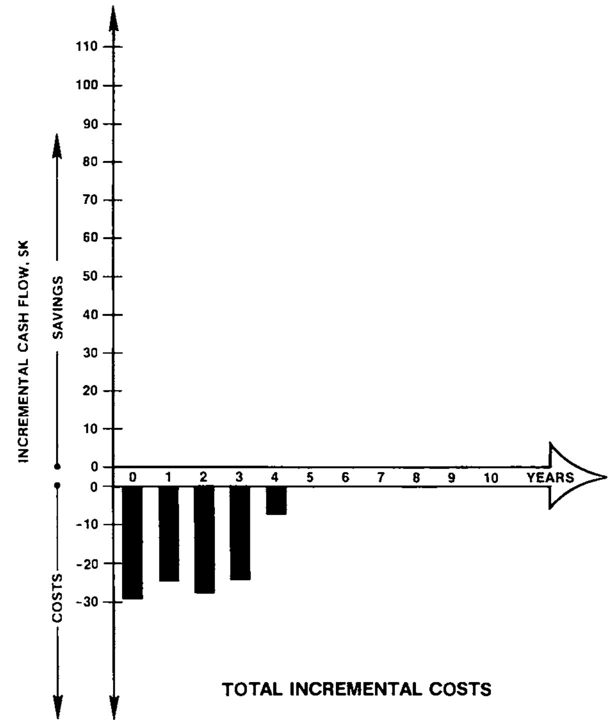
	YEARS					
	0	1	2	3	4	5-10
Forecast, Units	0	600	1,200	1,200	600	0
Annual Cost at $10.00	0	$6,000	$12,000	$12,000	$6,000	0



INCREMENTAL MATERIAL COST

SUMMARY OF INCREMENTAL COSTS

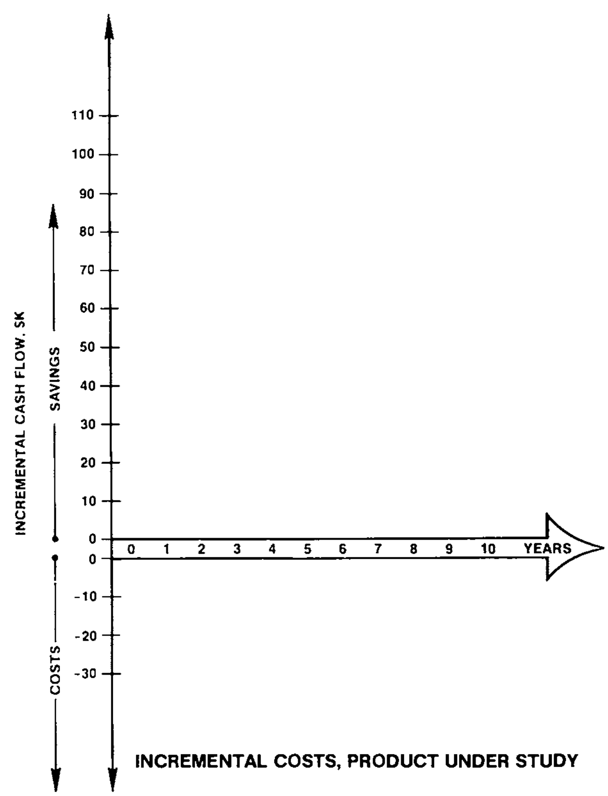
	YEARS					
COST ITEM	0	1	2	3	4	5-10
1. Engineering	15,000	0	0	0	0	0
2. Documentation	10,000	0	0	0	0	0
3. Test Equipment	2,000	8,000	5,000	2,000	0	0
4. Component Stock	0	9,000	9,000	9,000	0	0
5. Ongoing Materials	0	6,000	12,000	12,000	6,000	0
Totals	$27,000	$23,000	$26,000	$23,000	$6,000	0



TOTAL INCREMENTAL COSTS

INCREMENTAL COSTS, PRODUCT UNDER STUDY

	YEARS					
COST ITEM	0	1	2	3	4	5-10
1. Engineering						
2. Documentation						
3. Test Equipment						
4. Component Stock						
5. Material						
Totals						



INCREMENTAL COSTS, PRODUCT UNDER STUDY

SECTION E — ANALYSIS OF INCREMENTAL SAVINGS

By implementing the new digital test/service strategy, we experience significant incremental savings over the current strategy, in these cost areas:

1. Production Labor
2. Warranty
3. Field Service
4. PC Board Stock

Here is a detailed analysis of each of the incremental savings areas. The results are summarized at the end of the section, and space is provided to analyze incremental savings for another product.

1. **Production Labor**
   a. **Description.** The new strategy utilizes Signature Analysis to generate substantial savings in the final assembly troubleshooting area. This is because a final test technician can now make component level repairs in about the same time as it formerly took just to locate and verify a bad board.
   b. **General Rule.** Isolate the average time per unit normally spent on troubleshooting and repairing an assembled product on the line, and reduce it, 2:1.
   c. **Actual Experience.** Most cases do not generate "before/after" data since, when Signature Analysis is employed, the "before" case is never practiced. However, those cases we have studied show time improvements from 4:1 to 8:1. Therefore, the general rule, above, is very conservative.
   d. **Sample Product.** Using the 2:1 rule, and a cost breakdown for the sample product (Section B-3), we calculate production labor savings of $50.00 per unit.

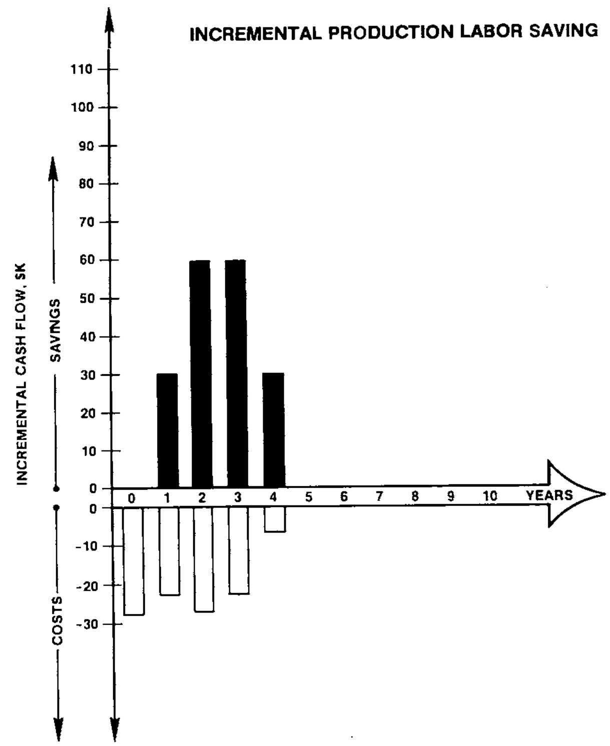
	HOURS PER UNIT		
TYPE OF LABOR	BEFORE	AFTER	SAVED
SUBASSEMBLY	4	4	0
FINAL ASSEMBLY	6	6	0
TEST	5	5	0
TROUBLESHOOTING	10	5	5
TOTAL HOURS	25	20	5
COST AT $10.00 PER HOUR	$250.00	$200.00	$50.00

This unit saving is then applied to the forecast (Section B-7) to obtain the annual incremental saving.

   e. **Timing.** Production labor savings are realized as follows:

INCREMENTAL PRODUCTION LABOR SAVING

	YEARS					
	0	1	2	3	4	5-10
FORECAST	0	600	1,200	1,200	600	0
ANNUAL SAVINGS AT $50.00	0	$30,000	$60,000	$60,000	$30,000	0



2. **Warranty**
   a. **Description.** By repairing PC boards in the field, instead of at the factory, we generate savings in the operation of a board exchange program in the areas of:
      - inventory.
      - administration.
      - logistics/distribution.
      - no-trouble-found boards.

      The repair cost reduction impacts both warranty and field service savings.
   b. **General Rule.** This can be a complex area in which to make estimates. However, the following formula is conservatively safe:

      Savings per repair =
      Average board exchange price (before).
      Less: Average repair parts price (after).
      Less: Incremental field repair labor (after).

      Some rules of thumb are:
      (1) Average board exchange price - $100.00.
      (2) Average repair parts price - $10.00.
      (3) Average incremental field repair labor - 1 hour = $10.00.

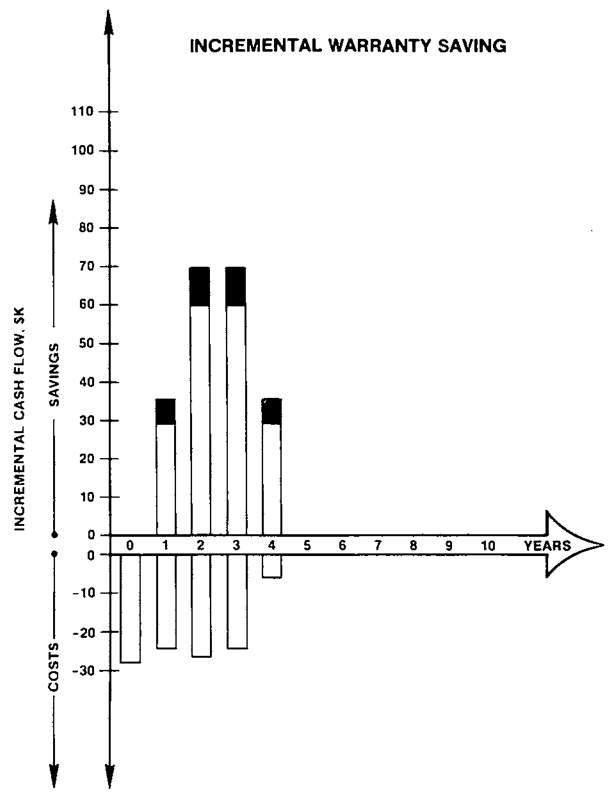
      Therefore, a conservatively low saving figure would be $80.00 per repair. This assumes that the former board exchange fee was set in such a way as to just cover the costs of running the program.
   c. **Actual Experience.**
      (1) Board exchange prices range from $50.00 to $500.00.
      (2) Repair component prices range from $.50 to $50.00.
      (3) Incremental labor is often well below the minimum charge, since boards can usually be repaired at the field office in the same time it formerly took to verify the bad board, process paper work and handle shipping.
      (4) The $80.00 figure is conservative.

d. **Sample Product.** We applied the $80.00-per-repair figure to the projected warranty failure rate (Section B-8) to obtain the annual incremental saving.

e. **Timing.** Warranty savings are realized as follows:

INCREMENTAL WARRANTY SAVING

	YEARS					
	0	1	2	3	4	5-10
WARRANTY FAILURES	0	60	120	120	60	0
SAVINGS AT $80.00	0	$4,800	$9,600	$9,600	$4,800	0



3. **Field Service**

a. **Description.** Same as 2-a, above.

b. **General Rule.** $80.00 per repair.

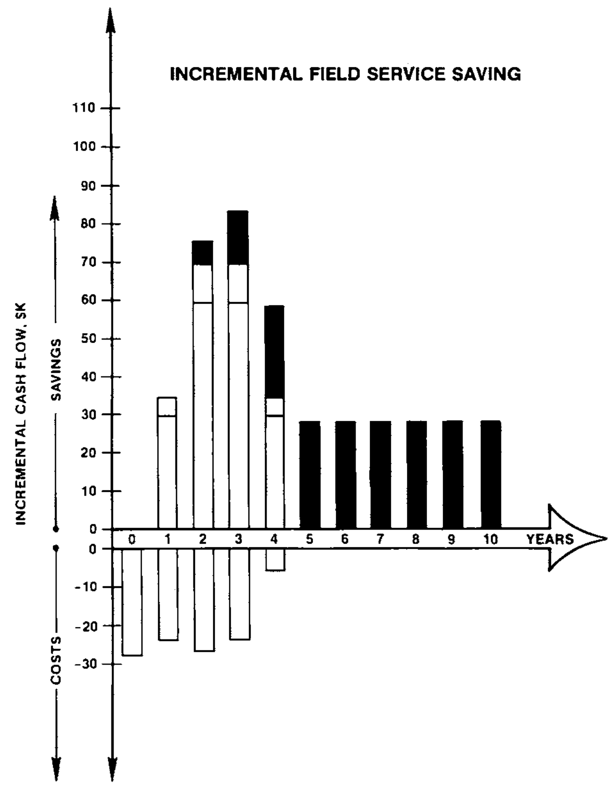
c. **Actual Experience.** Same as 2-c, above.

d. **Sample Product.** We applied the $80.00-per-repair figure to the projected non-warranty failure rate (Section B-8) to obtain the annual incremental saving.

e. **Timing.** Field service savings are realized as follows:

INCREMENTAL FIELD SERVICE SAVING

	YEARS					
	0	1	2	3	4	5-10
NON—WARRANTY FAILURES	0	0	60	180	300	360
SAVINGS AT $80.00	0	0	$4,800	$14,400	$24,000	$28,800



4. **PC Board Stock**

a. **Description.** The new strategy requires parts kits in field offices for component-level repair (Section D-4). Because of that, fewer board kits will be required in field offices. Board kits will be required only for on-site repair, with the bad boards being repaired at the field office. The reduction in startup board kits constitutes an incremental saving for the new strategy.

b. **General Rule.** Calculate the number of board kits required under the current strategy, enough to cover 2 months' failures at the projected mature failure rate. Calculate the number of board kits required under the new strategy, about one-third of the current figure. The difference in numbers of kits is the saving. A good approximation of kit cost is the product's material cost. Usually, with Signature Analysis, a stripped mainframe of the product is required in each office, in order to power the board for troubleshooting. So, from the board kit saving, be sure to deduct the cost of a mainframe for each office. Again, the product material cost should cover this.

c. **Actual Experience.** Reports indicate that the reduction of board kits is usually more than outlined above. The current strategy often requires 3 months' failure coverage, due to pipeline and turnaround problems. The new strategy often requires only 1 board kit per field office.

d. **Sample Product.**

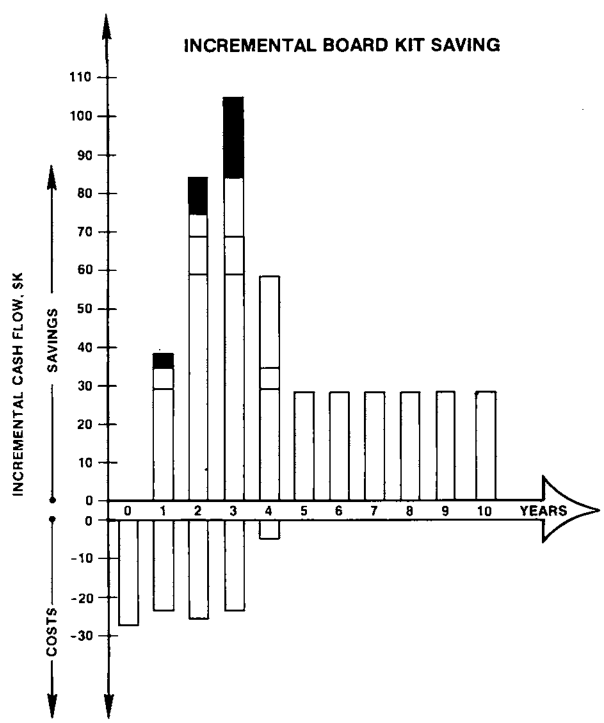
(1) **"Before"** — Projected mature failure rate is 30 per month (Section B-8). Two months' coverage would be 60 kits. Cost per kit (material cost in Section B-3) is $1,000, for a total of $60,000.

(2) **"After"** — One-third of the "before" figure is 20 kits, or $20,000.
(3) **Mainframes** — One stripped mainframe, at material cost, for each of the five field offices amounts to $5,000.
(4) **Total Saving** — $60,000 less $20,000, less $5,000 = $35,000.

e. **Timing.** The $35,000 saving in board kits is distributed over 3 years, as the kits would have flowed into the field pipeline with the growing service base.

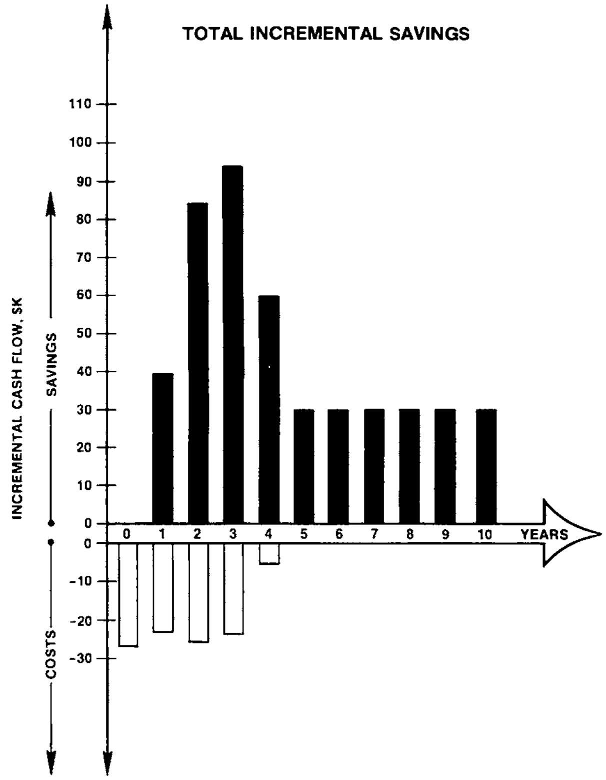
INCREMENTAL BOARD KIT SAVING

	YEARS					
	0	1	2	3	4	5-10
KITS REQUIRED, BEFORE	0	20	20	20	0	0
LESS KITS REQUIRED, AFTER	0	–10	–10	0	0	0
KITS SAVED	0	10	10	20	0	0
COST SAVINGS AT $1,000	0	$10,000	$10,000	$20,000	0	0
LESS SERVICE MAIN-FRAMES, 5 AT $1,000	0	–$ 5,000	0	0	0	0
NET SAVINGS	0	$ 5,000	$10,000	$20,000	0	0



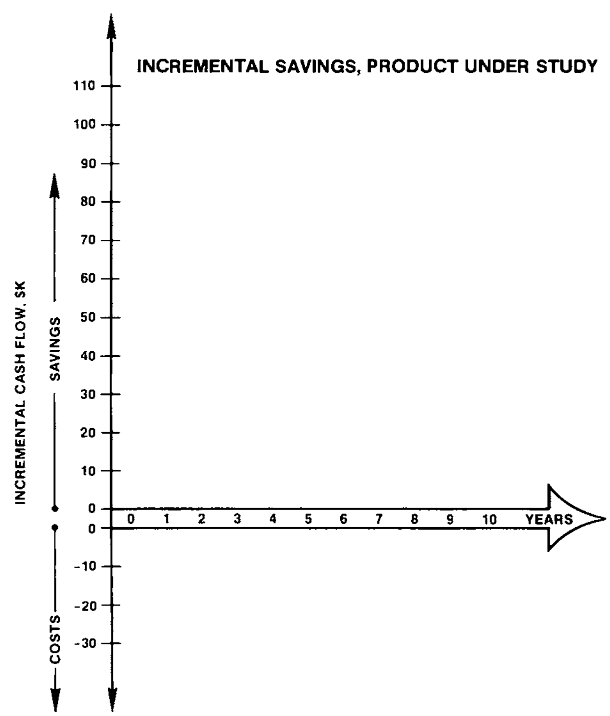
SUMMARY OF INCREMENTAL SAVINGS

	YEARS					
SAVINGS ITEMS	0	1	2	3	4	5-10
1. Production Labor	0	30,000	60,000	60,000	30,000	0
2. Warranty	0	4,800	9,600	9,600	4,800	0
3. Field Service	0	0	4,800	14,400	24,000	28,800
4. PC Board Stock	0	5,000	10,000	20,000	0	0
Totals	0	$39,800	$84,400	$104,000	$58,800	$28,800



INCREMENTAL SAVINGS, PRODUCT UNDER STUDY

	YEARS					
SAVINGS ITEMS	0	1	2	3	4	5-10
1. Production Labor						
2. Warranty						
3. Field Service						
4. PC Board Stock						
Totals						

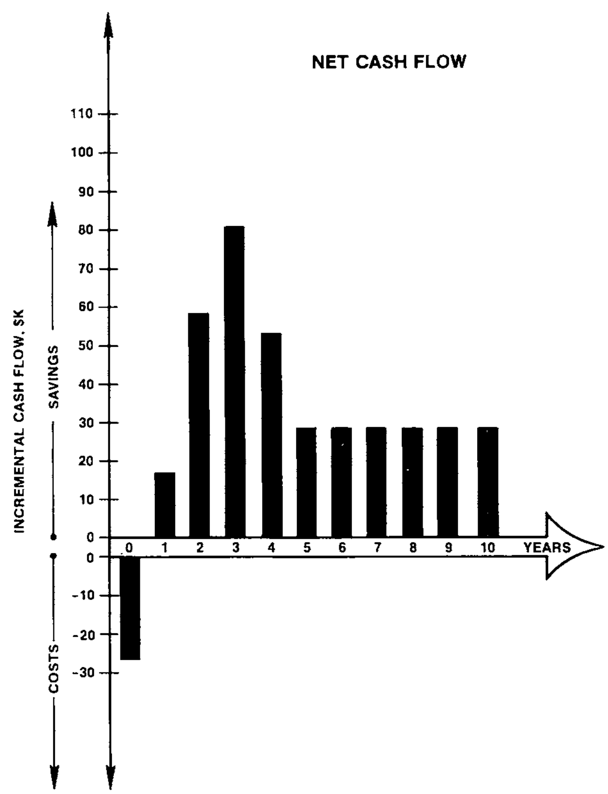


SECTION F — RETURN ON INVESTMENT

Once the incremental costs and savings are determined (Sections D and E), we can use them as data for any of the common return-on-investment calculations. We chose the IRR (internal rate of return) function of the Hewlett-Packard Model 38E Calculator. IRR is the compound interest rate which returns a series of positive and negative cash flows to zero present value. The cash flows for the sample product are:

ANNUAL INCREMENTAL CASH FLOW

YEAR	INCREMENTAL COSTS	INCREMENTAL SAVINGS	NET CASH FLOW
0	$27,000	0	$-27,000
1	23,000	$ 39,800	+16,800
2	26,000	84,400	+58,400
3	23,000	104,000	+81,000
4	6,000	58,800	+52,800
5	0	28,800	+28,800
6	0	28,800	+28,800
7	0	28,800	+28,800
8	0	28,800	+28,800
9	0	28,800	+28,800
10	0	28,800	+28,800

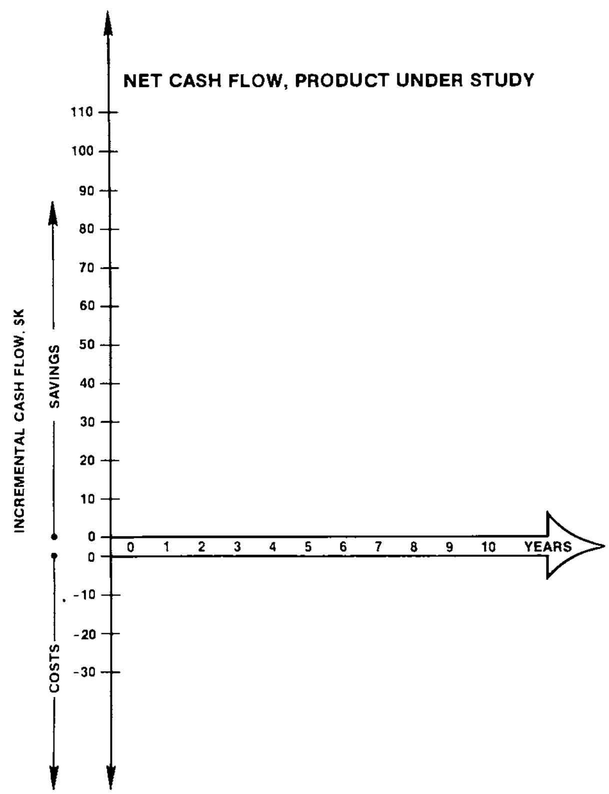


IRR = 132.6%

Note that, even though every effort was made to be conservative in the cost and saving estimates, the IRR is still very high for implementing the new digital test/service strategy. Here is space to calculate the cash flows and IRR for another product:

INCREMENTAL CASH FLOW, PRODUCT UNDER STUDY

YEAR	INCREMENTAL COSTS	INCREMENTAL SAVINGS	NET CASH FLOW
0			
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			



IRR = ______

The IRR calculation, above, was based on implementing a digital test/service strategy which took advantage of all the possible areas of savings offered by Signature Analysis. However, sometimes it is necessary to investigate the return of only a partial implementation of the technique. Here are two cases of interest:

Case 1—Include only production and warranty savings. Do not include field service savings, since the savings here may be passed on to customers via lower service charges. Or, the savings may be realized by a third-party service organization, not by the manufacturer.

Case 2—Include only production savings. This case assumes that Signature Analysis is used only in final assembly test, not in field service at all.

Case 1—All incremental costs are included (Section D) but only the following incremental savings are included:

- Production Labor (Section E-1)
- Warranty (Section E-2)
- PC Board Stock (Section E-4)

Field service savings are not included.

Case 2—Only those incremental costs are included which are required to set up a product for Signature Analysis in final assembly test:

- Engineering (Section D-1)
- Documentation (Section D-2)
- Test Equipment (Section D-3), reduced from 17 units to 7.
- Ongoing Materials (Section D-5).

Only those incremental savings are included which are realized in final assembly test:

- Production Labor (Section E-1).

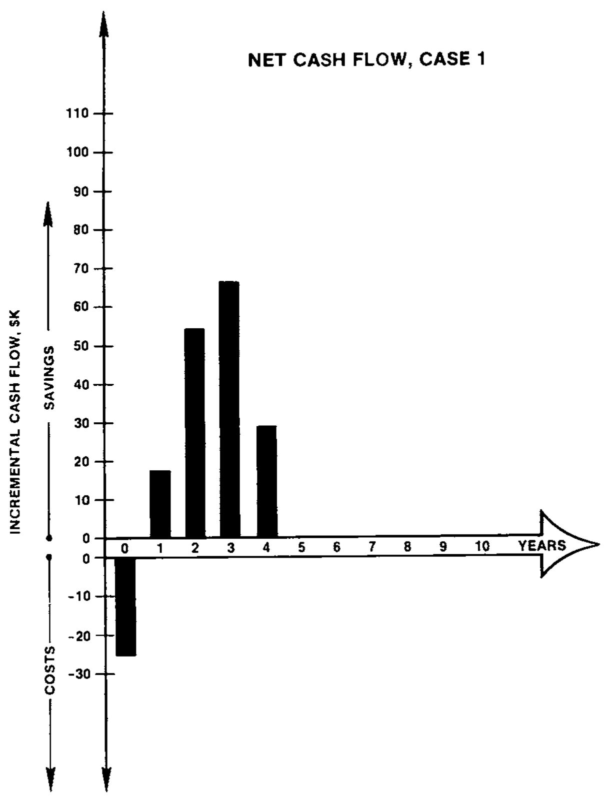
Warranty, field service and PC board stock savings are not included.

ANNUAL INCREMENTAL CASH FLOW, CASE 1

YEAR	INCREMENTAL COSTS	INCREMENTAL SAVINGS	NET CASH FLOW
0	$27,000	0	$-27,000
1	23,000	$39,800	+16,800
2	26,000	79,600	+53,600
3	23,000	89,600	+66,600
4	6,000	34,800	+28,800
5	0	0	0
6	0	0	0
7	0	0	0
8	0	0	0
9	0	0	0
10	0	0	0

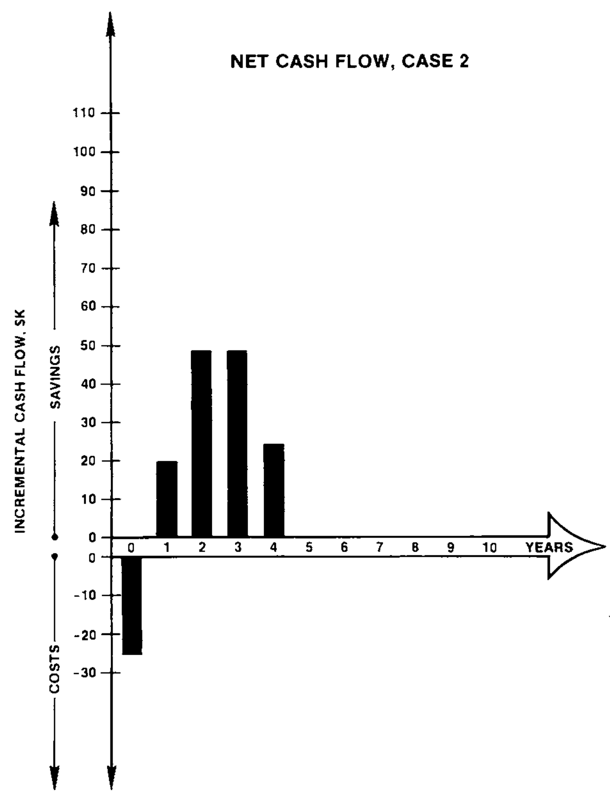
ANNUAL INCREMENTAL CASH FLOW, CASE 2

YEAR	INCREMENTAL COSTS	INCREMENTAL SAVINGS	NET CASH FLOW
0	$27,000	0	$-27,000
1	11,000	$30,000	+19,000
2	12,000	60,000	+48,000
3	12,000	60,000	+48,000
4	6,000	30,000	+24,000
5	0	0	0
6	0	0	0
7	0	0	0
8	0	0	0
9	0	0	0
10	0	0	0



IRR = 116.8%

In this case, eliminating field service savings still results in a very attractive IRR.



IRR = 107.4%

Even in this case, IRR is over 100%, in a situation where 20-30% is considered attractive.

SECTION G — CONCLUSION

1. **Summary.** The use of the model to compare two digital test/service strategies can also show the IRR derived by switching from one (current) strategy to another (new) one. A significant finding was that, even when the new Signature Analysis strategy was only partially implemented, the IRR was over 100%. This can be important in getting a new strategy started, by reducing the number of departments which must collaborate. In Sample Case 2, the Production Department could have justified the project on production savings alone. The Service Department would have had the option of adopting it later.

2. **Next Step.** The reader may apply the model to another product by utilizing the blank tables and plots in the paper. Here is an index to them:

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02-5952-7592 OCTOBER 1980 Printed in U.S.A.