How can TeraLogic enter the digital industry?

Strategic Research Group

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June 6, 1997

Acknowledgement

We would like to thank Dr. Peng H. Ang, Murray L. McLachlan, and Kishore Manghnani of TeraLogic, Inc. for their help in making this project possible. Also, we want to thank Professor Weyant and Tom Hoff for teaching us the numerous concepts and analytical tools to solving strategy problems. Lastly, we want to thank the many friends and strangers who took time to answer our diffusion and conjoint analyses surveys. Many thanks to all.

The Strategic Research Group

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Executive Summary

TeraLogic, Inc. (Mountain View, CA) is a venture based company specializing in semiconductor design and software products. Led by Dr. Charles Chui, a world authority on information theory, TeraLogic's technology team has developed an entirely new approach to image data compression called TeraLogic wavelet. The company believes this new technology will be highly valuable to the digital camera industry, which currently uses the entrenched JPEG standard to compress images. TeraLogic's approach adds value by enabling camera manufacturers to deliver higher quality images (that are thus more data intensive) without incurring higher costs.

There are three strategic alternatives available to TeraLogic today:

(1) License the technology to digital camera manufactures.

(2) Manufacture wavelet chips (integrated circuits) as off-the-shelf components.

(3) Wait and observe the market.

Our analysis suggests that the first alternative maximizes the net present value of the expected cash flows. Having said that, we recognize that the desirability of each alternative depends on one's assumptions about key sources of uncertainty, which is something we articulate further in the *valuation* section of this report.

Optimal Strategy
License wavelet technology to digital camera manufacturers for $500,000 up front and 4% royalty on future sales.

Problem Statement

TeraLogic's expressed purpose is to harness their skills in semiconductor design and software products to capitalize on the digitization of commercial products. The trend in digitization began roughly ten years ago with the introduction of compact discs that stored music in a digital format, as opposed to the conventional analog format used in cassette tapes. More recently, products such as cameras have begun to "go digital," starting with Apple Computer's revolutionary QuickTake 100 that was introduced in 1993.

The idea behind a digital camera is that it captures an image electronically , compresses the data, and stores it in memory until the data can be downloaded onto a computer to be processed. Digital cameras have yet to gain wide commercial acceptance largely due to their high price-to-quality ratio. To preserve image quality, one cannot compress the data too much, otherwise there will not be enough information left from which to reconstruct the image. But high image quality and low compression ratios mean that more memory is needed, and this costs money. No matter how one juggles the trade-off between image quality and required memory, it will be difficult to significantly increase the price-to-quality ratio since both variables are positively related with each other.

TeraLogic has developed a new data compression algorithm that demonstrates superior performance over the existing standard (JPEG). JPEG stands for Joint Photographic Experts Group and, as the name implies, it is a group of people from related industries that form a consensus on methods of image compression in order to create compatibility across products. From a technical standpoint, the JPEG standard is based on the discrete cosine transform algorithm, which is a discretization of the cosine (Fourier) integral transform while TeraLogic uses the wavelet approach, which makes use of certain "small waves" to build bigger waves that constitute a image. From here on, we will simply refer to the two algorithms as JPEG and wavelet. The photograph on the following page compares JPEG and wavelet performance using a

100x compression ratio (original image is 200K, reduced to 2K as shown). Notice how the JPEG frame contains block-type degradation.

TeraLogic Wavelet **JPEG**

Wavelet technology translates to less required memory for an image of a given quality. This represents a significant breakthrough since it promises to overcome the very hurdle that has been preventing digital cameras from winning over the consumer market. In essence, it is now possible to “give more quality” without charging the consumer for the cost of additional memory. We would expect digital camera manufacturers to jump at this new technology but the story is not that simple since JPEG is an entrenched standard. The switching costs are high indeed, and any manufacturer that bets its future on wavelet stands the risk of having an incompatible product if others do not fuel the wavelet inertia. From an investment point of view, wavelet technology may offer a high expected rate of return but is at the same time very risky due to the uncertainty concerning compatibility. This large “variance” in potential return clearly reduces the value of the investment.

This report tries to ascertain the value of wavelet technology to TeraLogic. Many factors undoubtedly influence this figure, chief among them being consumer demand and the nature of the manufacturer's industry. The value also depends on TeraLogic's course of action. The company may choose to license the technology, design its own application specific chips that incorporate the algorithm, or simply choose to wait. We will analyze these alternatives and recommend an optimal course of action as the report unfolds.

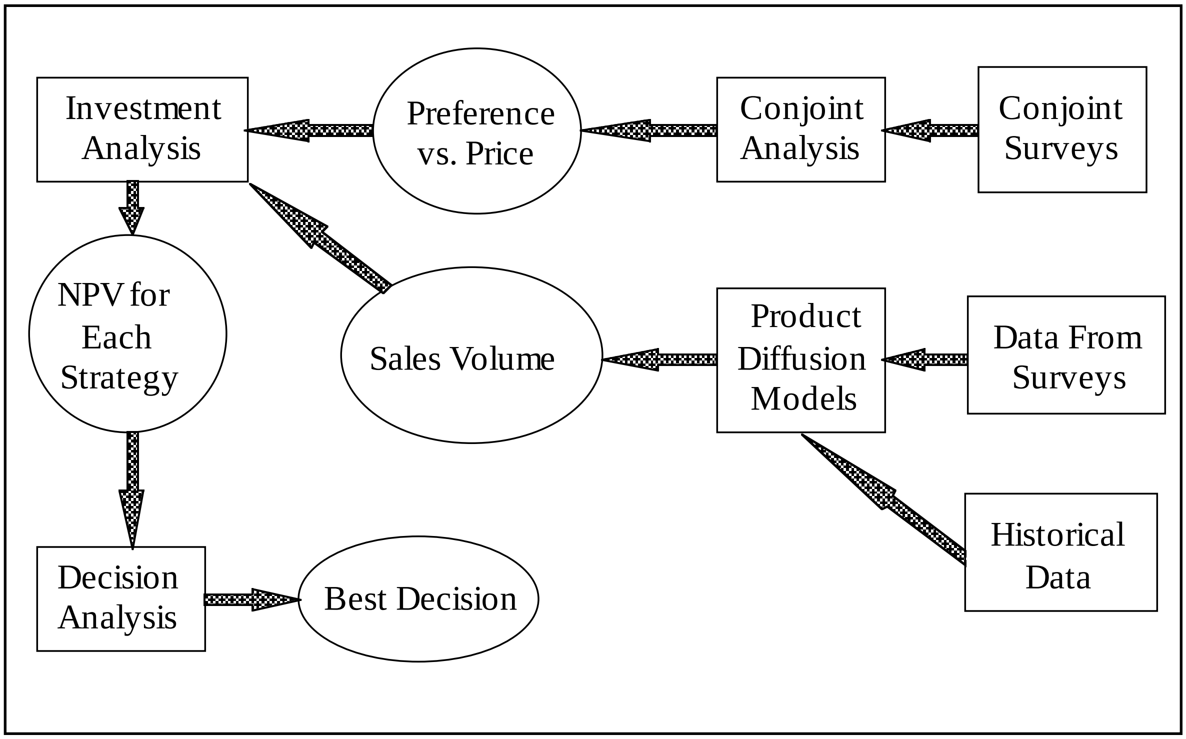
Overall Approach

Our task is to value the three alternatives available to TeraLogic. We focus on valuing the licensing alternative for two reasons. Firstly, this is most intuitively compelling. Start-up companies with hot technologies usually license their intellectual property since they often lack the resources to invest in other portions of the value chain that are necessary for launching one's own product; even if this is done, they may lack expertise in these areas. Although the chip alternative, if undertaken, can be outsourced to foundries, it still requires a major investment in terms of chip design and testing. The second reason is that the licensing alternative demands the most analysis, meaning that assumptions made here can easily be extended to apply to the chip alternative. Once we ascertain how much licensing is worth, we can explore how sensitive its value is in relation to making a chip or waiting.

To value the licensing alternative, we need to know the demand for wavelet technology. First of all, who are the customers? Clearly, the manufacturers are TeraLogic's customers but we immediately realize that trying to extract the demand function from analyzing the manufacturers is problematic. One challenge concerns the confidentiality which protects such important information from being shared. Dealing with these companies also results in delays associated with beauracracy and time differences. These logistical concerns aside, we find that valuation cannot be performed by directly focusing on the manufacturers as drivers of wavelet demand. This is because they are not. It is the end consumer, voting with his/her money, that dictates the market. Manufacturers are still trying to woo consumers to adopt digital cameras and thus will design new models that best reflect consumer preferences. Put another way, it is the consumers who demand wavelet technology (even though they do not articulate it as such), while the manufacturers serve as a middle entity that coordinates consumer preferences and available technology. We thus approach the project with an indirect method of valuation by first focusing on the manufacturer. Note that in doing so, we move one step closer to the consume r, and therefore can now incorporate consumer preferences directly into the analysis. Later on, we return to the original task and use the insights from studying the manufacturers to value wavelet technology for TeraLogic.

First of all, we measure the incremental value that manufacturers reap by switching from JPEG to wavelet based technology. This involves analyzing consumer preferences in order to derive a "willingness to pay" function that relates wavelet quality with cost. Next, we forecast the size of the digital camera market over time. We then combine the work from consumer preferences and sales forecasts, the former contributing prices and the latter furnishing quantities, to estimate how much revenue wavelet generates for the manufacturer. The switching costs involved in going from JPEG to wavelet are nontrivial, and we account for this when calculating profit margins, thus, arriving at the total size of the "wavelet pie." This is the total producer's surplus that is due to the wavelet technology. Assuming the surplus is, indeed, a positive quantity, we then turn our attention to how the pie will be sliced. The portion TeraLogic receives clearly depends on how well they can negotiate, which is really a question of bargaining power. The next section gives an overview of the digital camera industry by exploring how the various players relate to one another and in doing so, addresses the issue of bargaining power. Following that are sections on consumer preference and sales forecasting. Finally, the valuation section discusses the value model we employ to construct and evaluate cash flows. The diagram below illustrates the relationship between the various components of our approach. The rectangular boxes represent analytical methods while the circles represent the inputs and outputs to those tools.

Figure 1: Diagram for Project Approach: Analytical Methods



Industry Overview

We use Michael Porter's classic “Five Forces” framework to gain a fundamental understanding of the digital camera industry from the point of view of a camera manufacturer. The five forces are: rivalry among existing competitors, bargaining power of buyers, bargaining power of suppliers, threat of new entrants, and threat of substitute products.

Rivalry

Several manufacturers (around fifteen) are jockeying for position in this new market. Currently, no company has been able to establish market leadership, as evidenced by the relatively even distribution of market share. The race to deliver better quality at a lower price is intense indeed, giving rise to very shortly lived competitive advantages to any manufacturer that introduces a new camera. This is good news for TeraLogic, since it offers a manufacturer the chance to leapfrog past others in offering superior quality at a price-quality ratio that JPEG cannot achieve. Such an advantage could be long-lasting depending on the degree of exclusivity the manufacturer can enjoy from using wavelet technology.

Buyers

Upon first glance, buyers do not seem to have much power since the concentration of this "market" is extremely dilute: consumers do not collude to buy digital cameras in large quantities but rather, buy them individually in very separate circumstances. We cannot conclude, however, that buyers have little power because they have the option to not buy digital cameras. Clearly, if digital cameras were the only product available that captured still images, the story would be very different. It is precisely because digital cameras are *new* products that buyers enjoy power in their ability to refuse purchase until digital cameras demonstrate superiority over the traditional cameras to which buyers have easy access. The bargaining power of buyers is thus extremely strong in that they can cause the entire industry to collapse as long as they remain unconvinced of a digital camera's merit. As mentioned in the *approach* section, a main objective in our analysis is to ascertain the attributes that place digital cameras on par with their traditional counterparts.

Suppliers

The suppliers of digital camera manufacturers are software companies, technology suppliers (i.e. TeraLogic), lens manufacturers, battery manufacturers, RAM manufacturers, flash storage cards, etc. TeraLogic may not have much bargaining power as a supplier due to the following two reasons. Firstly, it is a start-up company that lacks brand recognition. Even though TeraLogic possesses a superior technology, most digital camera manufacturers are likely to prefer cooperating with well-established companies with big names. Secondly, the current standard for image compression is JPEG. Almost all existing software applications support the JPEG file format. This fact will strongly influence the digital camera manufacturers in choosing the storage format for their digital cameras. Therefore, TeraLogic may not be in the best position to negotiate a good price for their wavelet technology.

New Entrants

The possibility for new entrants is important because it gives a sense of how contestable the digital camera market is. In a highly contestable market, profit margins can be driven down to almost zero since as long as there is profit to be made, a new firm would enter. Fortunately for existing manufacturers (that are already engaged in intense rivalry), it is relatively difficult for a new manufacturer to enter because of the high fixed and R&D costs involved. However, given the nature of the product, it is possible that other well established electronic companies with deep pockets may enter the market. Specifically, computer companies such as Hewlett Packard may be interested in dabbling in digital cameras to develop imaging technologies that it can later use as a core competency in other products.

Substitute Products

Quite obviously, traditional analog cameras are substitute products. In fact, they are *entrenched* substitute products. Currently, analog cameras offer superior picture quality over digital cameras. In addition, the price of digital cameras is not yet as competitive that of analog cameras. Because analog and digital cameras are fundamentally cameras, the two will always be substitutable. Digital camera manufacturers need to entice consumers into buying their product by offering not only comparable but superior price-quality ratios in addition to novel features that analog cameras cannot substitute.

Consumer Preferences: Conjoint Analysis

Recall that the goal of this section is to ascertain consumers' willingness to pay for wavelet technology. We know that this new technology is able to compress data more efficiently than

JPEG, which translates into more data being stored per unit of memory. Most digital cameras available today offer 640x480 pixels of resolution, with the next step up in image quality at 1024x768 pixels (roughly a threefold increase in complexity). For simplicity, we refer to the former as quality A and to the latter as quality B. It turns out that the wavelet approach is roughly three times more efficient than JPEG, which means that a camera using wavelet technology can store an image at quality B on the same amount of memory that JPEG would require to store the same image at quality A. What this means is that we can use the quality specifications as proxies for wavelet and JPEG, thus taking their willingness to pay for upgrades in image quality to be synonymous with their willingness to pay for wavelet technology. As the standard of image quality improves, wavelet retains its competitive advantage over JPEG since the algorithm maintains (and in most cases *improves*) its efficiency relative to JPEG. For example, when most cameras begin to offer quality B in the future, wavelet can still offer quality C (1600x1200 pixels) for the same amount of memory.

The idea behind Conjoint Analysis is to use utility levels to determine how consumers value certain attributes of a product. Once we quantify values this way, we can explore how consumers are likely to trade off between changes in various attributes by extrapolating from their utility curves. Using the Sawtooth Software ACA System program, an on-line conjoint analysis survey was developed. This software program allows the user to identify an attribute hierarchy, specify question parameters, and customize computer screen templates to be used to generate and record the answers to the conjoint questions in real time. This method was used to allow subjects to directly input their responses into a computer. The Sawtooth program performs a linear regression comparing relative responses by potential customers to different permutations of product attributes. It does an initial analysis of all the attributes to determine the most important ones, and then does a pairwise comparison to determine relevance issues.

The results of the conjoint analysis software are a set of utility levels corresponding to each attribute that represents their relative importance to each other. For example, if one attribute has a utility value that is twice the utility value of another attribute, then the first attribute is twice as important as the second attribute. Thirty people completed the software survey. We sampled a wide cross section of the population which ranges from housewives to engineers with ages 20 through 50. Each was asked to evaluate the following attributes:

Picture Storage:	20, 40, 60, 80, or 100 pictures
Image Resolution:	640x480, 1024x768 or 1600x1200
Price:	$200, $400, $600, $800 or $1000

Picture storage

From the above utility values, consumers indicate that there is no strong preference from picture storage beyond 40. This result suggests that the consumers' mind-set of a digital camera has not shifted from the traditional analog camera storage of 12, 24 and 36 pictures. It may also indicate that most consumers do not need more than the capacity to store 40 pictures in a digital camera. Due to the memory management capabilities of a digital camera (ability to review and delete stored pictures), there is not a strong desire for consumers to purchase more memories to store more pictures.

Image Resolution

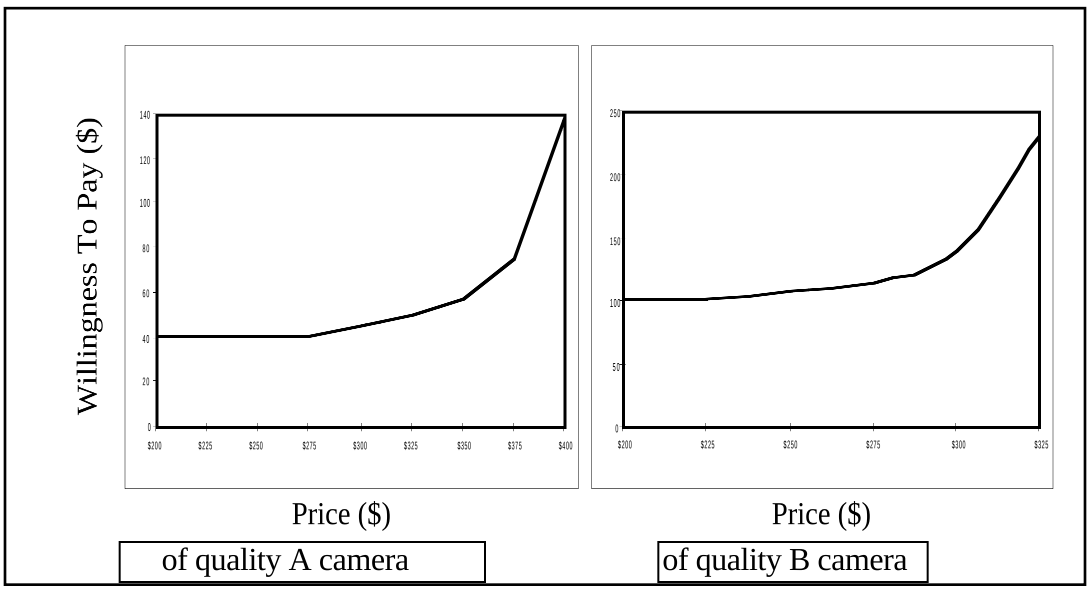
Consumers are demanding higher image resolution from digital cameras. The digital cameras that were offered in the past three years have been of low resolution (320 x 240 pixels). From the image resolution utility plot, we observe the predicted result that consumers are strongly biased toward the best resolution. This utility plot suggests that consumers would be willing to pay for even higher image resolution.

Price

The utility values for digital camera prices clearly indicate that the vast majority of consumers are only willing to spend around $200 to $400 for a digital camera. Less than 10% of the consumers are willing to spend more than that.

General Remarks

Having found that picture storage is relatively unimportant, we focus on the tradeoff between image quality and price in order to arrive at the willingness to pay for wavelet technology. The software generates the following two plots:



Upgrading from quality A to B

Upgrading from quality B to C

Figure 3

As an example, if the JPEG (quality A) digital camera is priced at $200, then consumers would be willing to pay an extra $40 for a wavelet (quality B) camera. Mathematically, the software uses utility levels to find indifferences between two “bundles” or offerings. Hence,

$$\mathbf{U\ (-\$200,\ quality\ A) \approx U\ (-\$240,\ quality\ B)}$$

where U stands for utility and ≈ indicates indifference. We find that the willingness to pay expressed as a percentage of the base camera is *fairly constant* at 20% for going from quality A to

B and 50% for going from quality B to C. This increase suggests that the value of wavelet technology will only increase with time since it is usually the case that incremental improvements are more highly valued as the overall state of technology improves. We will later use the 20% and 50% figures to apply to current camera prices that are in the $600 to $700 range (See **Appendix B** for a current listing of cameras).

As a closing observation, note that the survey results point to the ideal digital camera having the following attributes: 40 pictures of storage, 1600x1200 resolution, and a $200 price point. This clearly shows there is quite a long way to go before digital cameras can hope to be everyday consumer products.

Product Diffusion Analysis

In this section, we forecast the sales of digital cameras and then try to predict what fraction thereof applies to wavelet-based cameras. What makes this difficult is the fact that the market is still in its infancy; accurate data is extremely difficult to locate, and the little that can be gleaned is insufficient for establishing a trend. Parenthetically, manufacturers themselves are not very sure of the statistics; we are thankful to Alexis Gerard, a consultant in the digital graphics industry, for giving us approximate numbers. In the past, marketing personnel have used product diffusion models, which use dynamic equations to characterize consumer behavior, to forecast future sales in new markets.

Total Digital Camera Sales

In our analysis, we used the simple Bass (1969) model, which contains the effects of innovators and imitators. An innovator is a customer who purchases a product because of one's own interest in the product's features. An imitator is a customer who purchases a product because of their mimicking other customers' purchasing behaviors. The effects of the innovators and imitators and the potential digital camera market size are constant in our Bass model since these parameters are all assumed to be time-invariant.

Assumptions

1. One time purchase

    - Since digital cameras are "non-perishable" and relatively expensive, we assume that customers will buy at most one camera within the next five years. There are no repeat consumers.

2. Five year data survey

    - The purchasing time horizon in our survey is from 1993 up to 2000. Digital cameras have been introduced for three years, and we collected a five-year data survey in the market. TeraLogic requires a payback within five years in order to proceed with the project; thus, our initial evaluation focuses on a five year time frame.

3. Annual time interval

    - The time interval is yearly because smaller time interval would not give us more information about the market size of digital camera such as seasonal fluctuations in demand.

Model Inputs

Digital cameras have established a presence in the consumer market since its introduction in 1993. We obtained data of the consumer buying patterns of these cameras from TeraLogic's market research. Now, we want to project the likelihood that consumers would purchase a digital camera within the next five years. To obtain this information, we formulated customer surveys (Appendix D) to assist us forecast future demand for digital cameras.

We had a 63 survey respondents of which four already own a digital camera, 31 have plans to buy a digital camera within the next five years, and the remainder do not plan on buying a digital camera any time soon. To properly forecast the demand, we start our Bass model in 1993; thus, we are able to use actual purchase data for the first three years, and from our survey results, we project the demand for the next five years. These data are inputs for the Bass model.

Model Outputs

Figuring out the parameters in our Bass model by regression, we then can generate the predicted number of new digital camera customers in period t and the predicted cumulative number of digital camera customers from period 0 through period t from our model. The Bass Model outputs give us a good approximation of the digital camera market demand in the next few years.

Bass Model Formulation

$$T(t) = p * m + (q-p) * Y(t) - q/m * [Y(t)]^2$$

T(t) is the number of units sold in time period **t**
Y(t) is the total number of units sold from period **0** to period **t**
m is the total market size
p is the coefficient of innovation (related to voluntary purchase)
q is the coefficient of imitation (related to influenced purchase)

Note that the model assumes a constant **p** and **q** throughout the modeling horizon. The Bass model also assumes that the product in question is a durable good, meaning buyers would buy no more than one unit (no repeat purchases).

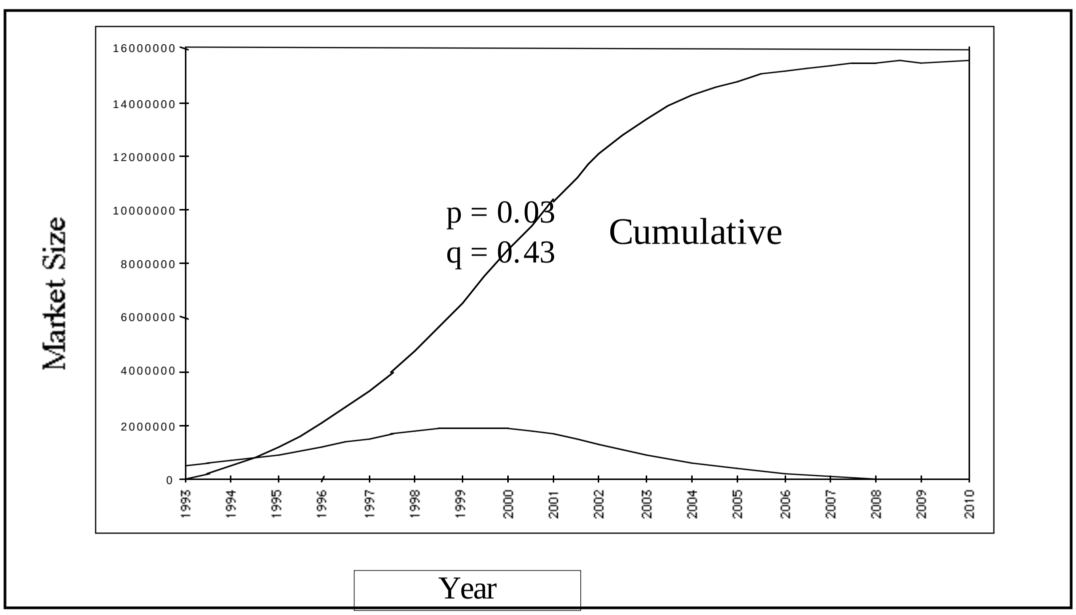


Figure 2

General Remarks

We used the Least Squares method to curve fit the survey data. From our model calculation, the best estimated coefficient of innovation, p, is 0.03, and the best estimated coefficient of imitation is 0.43. Given that the actual market size of digital camera in 1997 is about 3.285 million, we set our cumulative number of digital camera purchasers from year 1993 to year 1997 to be this number. In such way, we figured out the proper potential market size of digital cameras, based on the actual data, to be roughly around 15.6 million. The prediction of the future market size is shown in Figure 2. As we can see, the market size increases dramatically in the next few years and reaches the maximum about 15.6 million in year 2009. Our model implies that mass consumers purchase would have a digital camera eventually, which is reasonable, since we assumed that the potential market size (m) is time invariant (constant over time) and both innovators and imitators have certain effects on the market.

Comparing our results with TeraLogic's rough estimation about the digital camera market sizes in the next few years, we found that our model predictions are fairly close to TeraLogic's estimations. TeraLogic might have estimated the market size in 1997 to be around 2 million, while our estimation is about 3.285 million. Our Bass Model projects total of 8.47 million customers by the year 2000, while TeraLogic predicts around 10 million.

Wavelet Camera Sales

From above, we have found the projected market size for the digital cameras. Now we forecast how wavelet technology will diffuse into the overall market. In order to understand wavelet penetration into the market, we perform the diffusion analysis again using three scenarios to frame our assumptions. These scenarios largely depend on decisions made by manufacturers early in the game (whether or not to switch to wavelet), and on how warmly the public receives the technology.

(1) **Wavelet makes Waves.** Camera manufacturers start to adopt the TeraLogic wavelet in their digital cameras. These manufacturers recognize the efficient compression and 3x smaller

file size superiority obtainable from wavelet compared to the JPEG technologies. These improved technology breakthroughs propel digital camera sales. Moreover, once the media starts to report of the trend and assist the transformation of the digital camera as a product for the mass consumer and not just a toy for the hobbyist, digital cameras will begin to replace analog cameras. Furthermore, wavelet's popularity and technological superiority gain recognition not only in the digital camera market place but also in the still-picture market; TeraLogic's wavelet technology becomes the de facto standard for still pictures, replacing the JPEG technology. The brand recognition and popularization of the TeraLogic wavelet in the still-pictures market will allow the company to capture a significant market share, and we anticipate this could be at least 75% in the long run.

(2) **The Calm Wavelet.** Camera manufacturers do not reach a consensus in the selection of a preferred format for picture storage. For example, Kodak selects JPEG, PhaseOne selects TIFF, and Minolta has their own proprietary format. Wide variations between vendors result in confusion in the consumer market. Hence, no camera is able to gain a leading market share because software vendors support all the different picture formats. Consumers are indifferent to the real format supported by the camera manufacturers just as long as they are able to view their photos. Formats and compression improvement are not stressed because camera manufacturers are able to derive improvements from the hardware camera implementation. For example, continuous device technology improvements speeds up microprocessing power and drives ram and storage costs downwards. Gains from the hardware front are far reaching compared to the compression algorithmic improvements. This scenario results in the lukewarm adoption of wavelet since all formats co-exist; each format can be treated as a "commodity product". No one format can demonstrate notable product differentiation. Hence, TeraLogic can at best achieve only 50% market share in the long run.

(3) **The Wavelet Crash.** Many digital camera manufacturers already have significant lead in their camera development using JPEG. TeraLogic's wavelet technology has difficult time catching up with the three year lead established by JPEG's presence in the digital camera market and in the still-picture market. Moreover, some camera manufacturers have already built wavelet

based camera using traditional wavelet algorithms and are dissatisfied by the significant computation required. Traditional wavelet algorithms have very slow compression and de-compression time; thus, the "click-to-click" time between shots is long. Bad experiences and poor reputation by previous wavelet introductions increase the barrier for TeraLogic's wavelet to enter the digital camera market. Due to poor market wavelet acceptance, TeraLogic can probably achieve a maximum of 10% market share.

We take the long run market shares for each scenario (75%, 50%, 10%) to scale the steady state region of the original diffusion curve. We then select p and q values noting that p generally ranges between 0 and 0.06, and q ranges from 0 an 0.9. So, for instance, a relative high value of p and q is selected for scenario (1), medium values for scenario (2), and low values of scenario (3). The resulting projections are displayed in Figure 4. Notice that wavelet starts emerging into the digital camera market in year 1999, when digital cameras with wavelet chips become available.

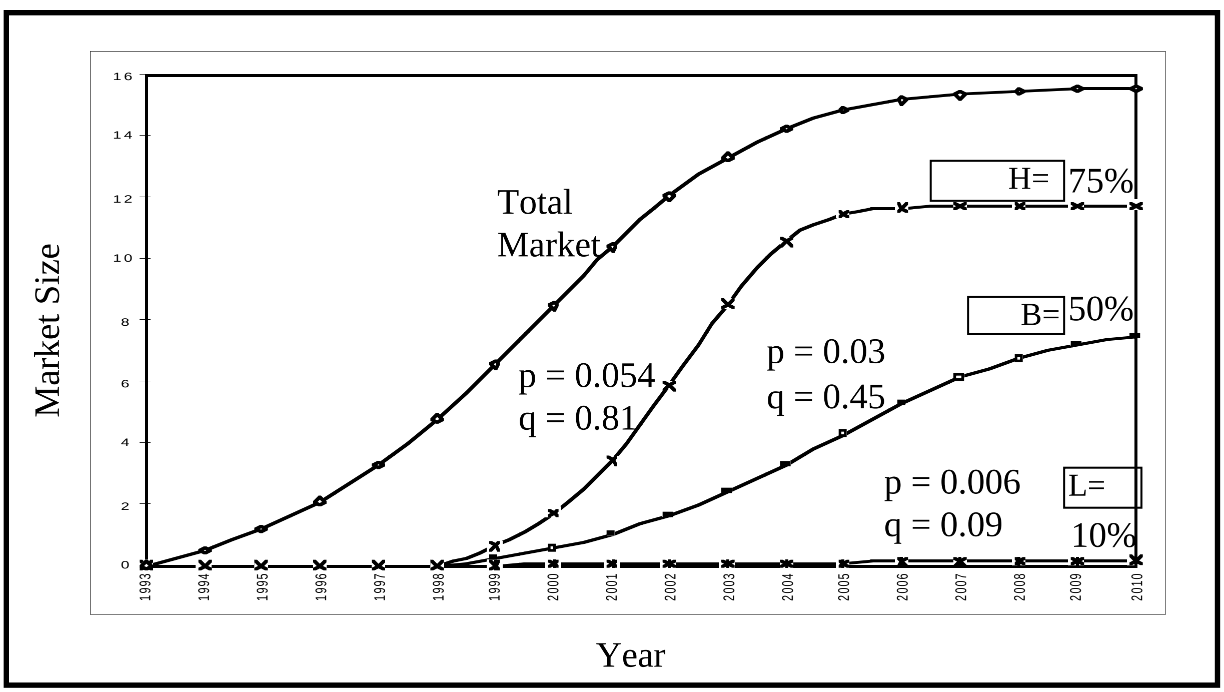


Figure 4

Valuations

In this section we place a value on the two main alternatives available to TeraLogic: licensing wavelet technology and implementing an application specific chip solution. In the case where it is *unprofitable* to do either, we recommend waiting to see if the market improves over time. At this point, there are too many sources of uncertainty to reasonably calculate the value of waiting in terms of an option. This is because we are dealing with a capital financing decision and NOT a securitized investment such as those found on the stock market (hence the replication method of valuation it suspect since the wait option is not a derivative and is thus by definition un-replicable). The wait alternative is actually an embedded option that greatly adds to the complexity of the calculations.

Before jumping to the results, we list the key assumptions of our model below.

- **Seven-Year Time Horizon**

The digital camera market is very young and still unproved, which means it is difficult to develop robust forecasts. The degree of variance increases as the modeling horizon increases, so it would be unreasonable to attach much significance to cash flows occurring in the distant future. The rapid pace of technological advancement that characterizes consumer electronic products also adds to cash flow volatility. We also recognize that TeraLogic is inclined to license its technology, and so need to consider a time horizon that well approximates the lifetime of technology licenses (standard practice is 5 to 10 years). Finally, we believe that a license should serve as a tool for TeraLogic to explore the profitability of the digital camera market and hence it makes sense to use a short-term license to create more flexibility for re-negotiation in the future.

- **No Positive Cash Flows until Year 2**

Assuming a manufacturer purchases the technology from TeraLogic today, our research shows that it would take eighteen to twenty-four months to design and implement a wavelet based camera. This means that wavelet related revenues can only begin two years from today.

- **Resolution over Time**

Quality A remains the standard until the year 2000, at which time quality B becomes the standard. This means that to be competitive, wavelet-based cameras start offering quality B in 2000 and then quality C in 2004.

- **Price Behavior**

We observe that digital cameras that set a new quality standard are introduced at around $750 and drop by $100 each year until they are either phased out or replaced by a the next generation's standard. Note that since the quality improves with each generation, the quality-price ration is effectively dropping, which we have seen is something that is necessary for consumers to rapidly adopt digital cameras.

- **Discount Rate**

TeraLogic uses a risk-incorporated discount rate ranging from 25% to 30% for investment opportunities such as technology licensing. We use the average value of 27.5% in the model.

(1) To License the Technology to Digital Camera Manufacturers

As explained earlier, we estimate an appropriate licensing fee by combining the total sales of wavelet digital cameras with a dollar amount that customers are willing to pay for the incremental benefit of wavelet technology, measure in terms of percentage of camera price.

We project the prices of future digital cameras by observing the historical data. When each camera model was first introduced, its price was around $750. The average price drop per year is around $100. We estimate that around year 1999, a majority of consumers will switch to a new digital camera model with a higher resolution; therefore, there is a shift up in price. Please refer to NPV calculation spreadsheet in Appendix E.

There are several costs associated with this alternative. First, there is a switching cost of around 5-10 million dollars (we use 7.5 millions in calculation) to switch from JPEG digital cameras to wavelet digital camera. Secondly, since we measure value of wavelet in terms of upgrade in resolution, we have to account for the incremental costs of CCD and RAM for a higher-resolution camera. We estimate the total incremental cost of this upgrade to be around $50 per camera.

By integrating the sales, the dollar values to customers, and the costs together, we have found the total value of wavelet technology to the digital camera manufacturers as shown in the first column of Table 1. To divide this "total pie" into two portions (one to the manufacturers and the other to TeraLogic), we use an approximation as follows. Royalties from licensing in the high-tech industry today range from 5% to 10%. Since royalties are meant to distribute earnings between a licenser and a licensee, we argue that a similar distribution takes place here, with some of the total wavelet pie being divided between the manufacturer (licensee) and TeraLogic (the licenser). Hence, we assume that an average of 7.5% of the total wavelet value goes to TeraLogic. To reiterate, this 7.5% is NOT a royalty rate but its motivation is derived from the concept of a royalty. The second column of Table 1 shows the license values to TeraLogic for the three scenarios. With $500,000 up-front fee as TeraLogic has suggested, we then recommend the royal rate of 4%-5.3% as displayed in the last column.

	Wavelet Value	License Value	Royalty
BASE	$96,463,973	$7,234,798	4.00%
LOW	($4,882,817)	$0	
HIGH	$436,014,428	$32,701,082	5.27%

* Assume up front is always $500,000 and 7.5% of total wavelet value to TeraLogic

Table 1: Summary of results for the alternative to license the technology

(2) To Manufacture the Wavelet Chips by TeraLogic Themselves

We also use the same projected sales for wavelet chips as in the previous alternative. However, to manufacture the chip themselves, TeraLogic will face the cost of designing, prototypes, samples, and marketing , and which would cost them around $2 million dollars. The chips manufactured will be priced at $10 each with the gross margin of 50%. These values were supplied to us by TeraLogic and our research. Table 2 summarizes the results from the spreadsheet in Appendix F.

	Chip Value	Choose CHIP alternative if can't get at least this royalty rate + $500K up-front
BASE	$1,682,782	0.7%
LOW	($1,485,116)	N/A
HIGH	$9,812,582	1.5%

Table 2: Summary of results for manufacturing the chips

The second column of Table 2 shows the break-even analysis for the two alternatives comparison. Specifically, TeraLogic should choose to manufacture the chips themselves only if they cannot negotiate for a royalty rate higher than 0.7%-1.5%.

Recommendations

From our analysis in the two alternatives: licensing or manufacturing, we conclude that licensing is a better option for TeraLogic. As we mentioned before, 7.5% of the total market profit gained from selling digital cameras would go to TeraLogic in seven years. If long-run market share of wavelet technology is 50% of the total digital camera market size(Base Case), we recommend the royal rate of 4% with $500,000 up-front fee, and TeraLogic is expected to earn $7.23 million in seven years. If wavelet technology acquires 75% market share (High Case), we recommend a 5.3% royalty rate with the $500,000 up-front fee. The expected revenue TeraLogic will gain is $32.7 million. However, if the market share is going to be only 10% (Low Case), we recommend TeraLogic not to enter the market now because TeraLogic sustain losses.

Due to the buyer's bargaining power for TeraLogic's wavelet technology, TeraLogic might not have the opportunity to require the corresponding royalty rate for each case. Therefore, TeraLogic should consider the chip manufacturing alternative. From our break-even analysis for licensing and chip manufacturing alternatives, we recommend that TeraLogic should manufacture wavelet chips themselves if the royalty rate is less than 0.7% in the base case and less than 1.5% in the high case. The following table summarizes our recommendations of different strategies that TeraLogic should pursue depending on the market climate.

	Strategy	**Value to Teralogic** (7 Year NPV @ 27.5% discount rate)	**Minimum Royalty Rate** (otherwise, go with Chip Alternative)
BASE	License ($500k + 4% royalty)	$7,234,798	0.7%
LOW	Wait	$0	N/A
HIGH	License ($500k + 5.3% royalty)	$32,701,082	1.5%

NOTE: Assume negotiation results in 7.5% of total wavelet market value

Table 3: Summary of recommendations

What We Have Learned From This Course

We found the project to be very stimulating and filled with complex and far-reaching issues. We believe that TeraLogic can provide competitive advantage with their wavelet technology. With this new superior technology, TeraLogic has great potential in capturing the digital camera market.

Through our analysis, we have gained greater insights to problem formulation and the underlying theories of different analytical methods. From expert interviews, library research, and contacts with TeraLogic, we have fine tuned our skills especially in the area of making assumptions. For example, in the process of forecasting market demand , we needed to make several assumptions. To best ensure the accuracy of our assumptions, we relied on research, experience, interviews, intuition, and a bit of luck such that now we have also become semi-experts in the digital camera industry. Hence, we were able to generate a demand curve that fitted well both with historical and predicted data. Practicing the analytical tools that we have learned in class to a real problem has given us deeper understanding and insights to the underlying workings of the Bass Model, Conjoint Analysis, Investment Valuation, and Strategic Scenarios. Moreover, this project has taught us how to formulate a “complete” analytical solution. For example, in the structuring of our problem, we were able to use the results of conjoint analysis and diffusion modeling to do our investment analysis . The process of capturing the overall approach, selection of appropriate tools to analyzing our problem, and finally providing a complete solution is one of our biggest hurdles which we have overcome. We feel very positive from this experience and will definitely be applying on the skills that we have gained through this course to our future projects.

Appendix A: Digital Camera Background

Digital cameras work and operate like typical point-and-shoot analog cameras. The similar features are a viewfinder, a flash, and a control panel that displays the status of the camera. However, digital cameras contain significant differences both from the user's as well as the manufacture's standpoint.

From the user's standpoint, digital cameras have the following advantages over analog cameras:

No film and processing costs

For an analog camera, taking regular pictures is expensive. Making a picture from film may cost up to $1 a shot when the fees of film and processing are included.

Instant gratification

The LCD screen on the digital camera enables the user to view the photo immediately after it has been taken. Any of the photos stored can be viewed on the LCD screen.

Photo Management Capability

The user is allowed to select and erase any of the photos taken. This makes using a digital camera more forgiving than using an analog camera.

Picture Editing Capability

Pictures taken with a digital camera can be quickly and easily downloaded into a PC, then the user can view and edit his photos with a wide variety of image editing softwares.

The disadvantages are:

Low Image Resolution

Most current point-and-shoot digital cameras have resolutions of 640x480 or 307,200 pixels. This resolution, when compared to a low-end analog camera (with each frame containing 100 million pixels), is inferior by far.

Low Image Quality

Digital camera images tend to be more blurry and of lower contrast as compared to low-end analog cameras. Colors can be washed out and straight lines often appear on digital images.

High Cost

The typical price of a 640x480 digital camera is three times the cost of an average analog camera, around $600 to $800. For a higher resolution digital camera, anything above 1024x768 costs more than $1,000.

Computer Dependent

The user must use a computer to download the images. There are no photo-finishing shops for digital cameras so the user must print the photos on a printer.

From the manufacturer's standpoint, digital cameras have internal components that are completely different from those of analog cameras. The former involve electronic components and the latter involve traditional film technology. Corresponding to the film of an analog camera, the image capturing component of the digital camera is the CCD(Charged Couple Device). The CCD directly gives the resolution of the electronic image-the finer the CCD, the higher the resolution. There are many disadvantages associated with the use of CCD such as high cost, high power consumption, slow response time, etc. Therefore, CMOS active pixel sensor (APS), which fares better than CCD's in those disadvantages, may replace it in the next couple of years. This is likely to lower the cost of digital cameras in the future.

Some other components of a digital camera are clock drivers, internal memory (for photo image storage), analog signal-processing devices (for color balance and exposure control), and a microprocessor (for picture compression and user capabilities).

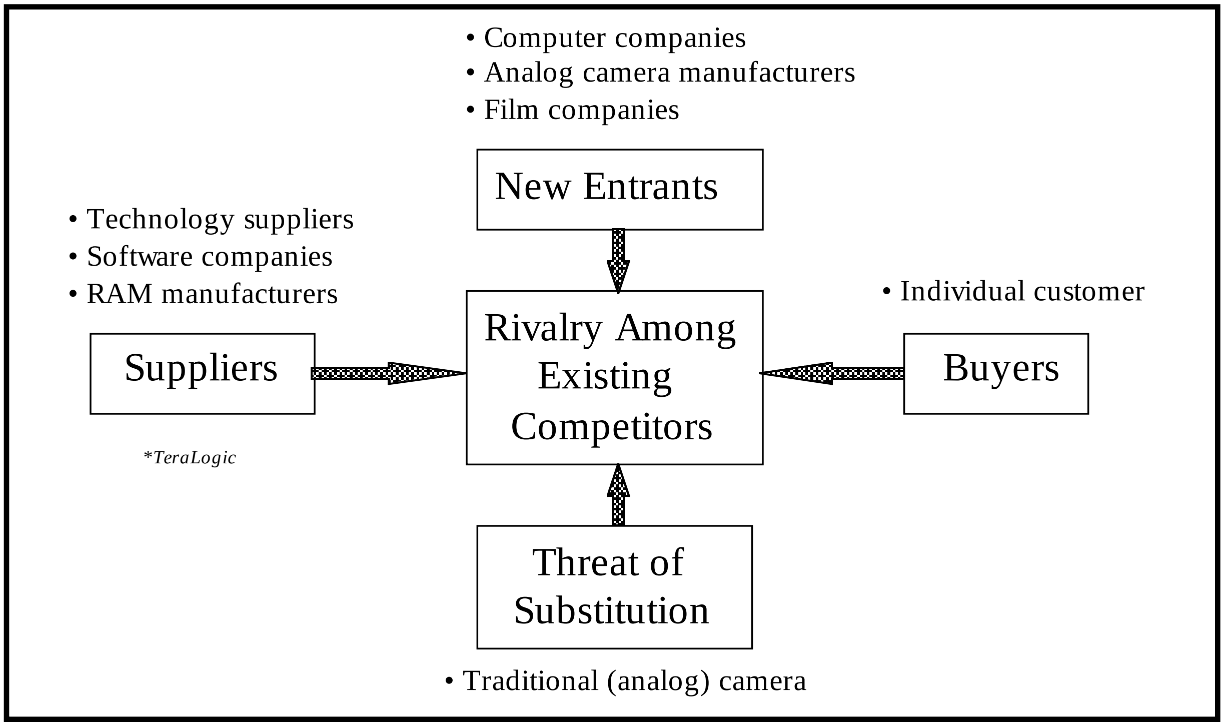
Appendix B: Digital Camera Price List

Price List of Digital Cameras (July 1997)

640x480 Resolution Digital Cameras

Agfa E-Photo 307	$549
Apple QuickTake 150	$599
Apple QuickTake 200	$599
Canon PowerShot 350	$699
Casio QV-100	$599
Casio QV-120	$499
Casio QV-300	$699
Dycam 10C	$649
Dycam 3	$695
Epson PhotoPC	$399
Epson PhotoPC 500	$499
Fuji DS 7	$599
Fuji DS-220	$999
Konica Q EZ	$399
Konica Q-Mini	$599
Minolta Dimaae V	$895
Olympus D-200L	$599
Sharp VE-LC1	$799
Sierra Imaging SD 640	$499
Sony DSC-F1	$850
Toshiba PDR-2	$499
Average Price	**$630**

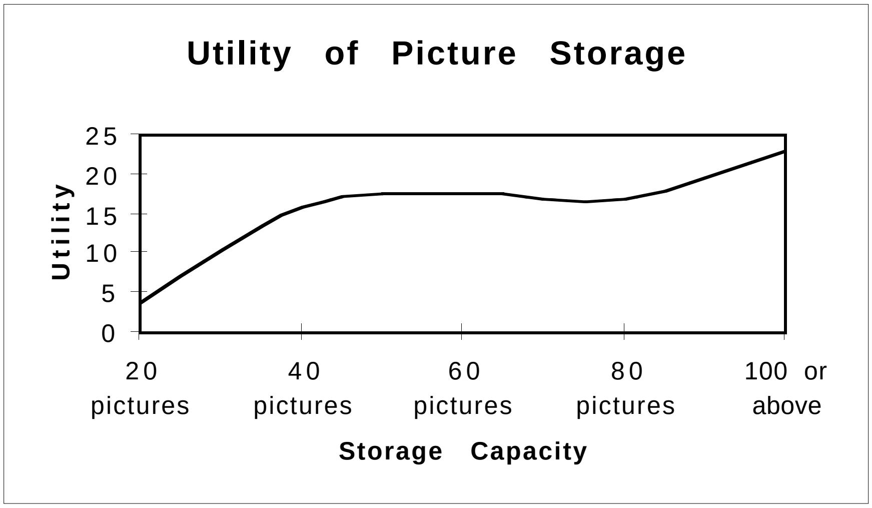
Appendix C: Competitive Forces in the Digital Market



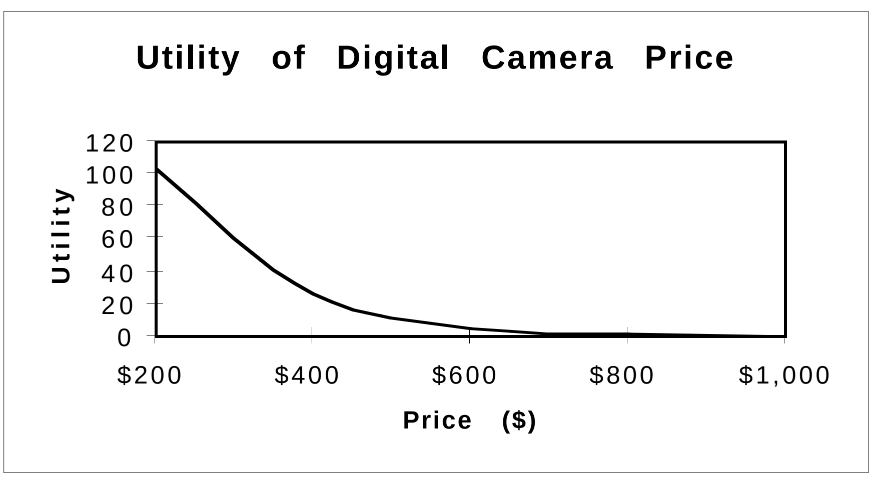
Appendix D: Utility Data from Conjoint Analysis

Picture Storage		**Image Resolution**		**Price**	
Level	*Utility*	*Level*	*Utility*	*Level*	*Utility*
20	3.75	640x480	1.15	$200	103.28
40	15.97	1024x768	18.14	$400	25.74
60	17.42	1600x1200	61.17	$600	5.37
80	16.8			$800	1.54
100 or above	23.12			$1,000	0.33

Price of Digital Camera	**640X480 JPEG 1024X768 Wavelet**	**1024X768 JPEG 640X480 Wavelet**
	Willingness to Pay	Willingness to Pay
$200	41	103
$225	41	103
$250	41	108
$275	41	115
$300	45	140
$325	50	232
$350	57	
$375	75	
$400	138	


Utility of Picture Storage
25
20
15
10
5
0
Utility
20 pictures
40 pictures
60 pictures
80 pictures
100 or above
Storage Capacity


Utility of Image Resolution
80
60
40
20
0
Utility
640*480
1024*768
!600*1200
Image Resolution


Utility of Digital Camera Price
120
100
80
60
40
20
0
Utility
$200
$400
$600
$800
$1,000
Price ($)

Appendix E: Diffusion Questionnaire

Please answer the following questions. Answers should follow the prompts (>).
Thank you!

(1) Do you think you would buy a digital camera in the next 5 years?

>

If NO, there are no more questions, thanks for your time.
If YES, please go to (2)

(2) How soon do you think you will buy a digital camera?

>

(3) When making the decision to buy, are you more influenced by advertising and the media in general or by people who have already bought?

>

If you said ADVERTISING, please go to (4) and STOP after that.
If you said FRIENDS, please go to (5)

(4) How likely are you to go out and buy a digital camera before talking to others about it? (Scale is 1 to 10 with 10 being most likely)

>

(5) How likely are you to go out and buy a digital camera if you start seeing most of your friends buying? (Scale is 1 to 10 with 10 being most likely)

>

Appendix F: Spreadsheet for Licensing Alternative

LICENSING OPTION (7-Year License)

Actual	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Model Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**
Price	650	550	450	750	650	550	450
WTP	130	110	90	375	325	275	225
Discount (RR)	**27.5%**		**Royalty**	**4.0%**			
Incremental Revenue	$0	$0	$21,046,943	$123,343,856	$146,879,173	$165,163,213	$171,372,918
PV(Revenue)	**$170,154,534**						
Incremental Cost	$52,500,000	$0	$11,692,746	$16,445,847	$22,596,796	$30,029,675	$38,082,871
PV(Cost)	**$73,690,561**						
Incremental Profit	($52,500,000)	$0	$9,354,197	$106,898,009	$124,282,377	$135,133,538	$133,290,047
NPV	**$96,463,973**						
TeraLogic gets 7.5%	**$7,234,798**	1682782					
		0.017444668					
Royalty cash Flow	**$0**	**$0**	**$841,878**	**$4,933,754**	**$5,875,167**	**$6,606,529**	**$6,854,917**
PV(Royalty)	$6,806,181.37						
License lump sum charge	**$500,000**						
Target	$7,306,181						
switch	1						

	BASE (1)	LOW (2)	HIGH (3)	ACTIVE
1997	0	0	0	**0**
1998	0	0	0	**0**
1999	233854.923	9354.196921	631408.2922	**233854.923**
2000	328916.9492	10134.8982	1081135.162	**328916.9492**
2001	451935.9175	10969.35435	1722924.831	**451935.9175**
2002	600593.5032	11859.15133	2411023.253	**600593.5032**
2003	761657.4119	12805.4971	2683478.844	**761657.4119**

Assume 14 manufacturers

14	7	Base
	1.4	Low
	10.5	High

Summary	Wavelet Value	License Value	Royalty
BASE	$96,463,973	$7,234,798	4.00%
LOW	($4,882,817)	$0	
HIGH	$436,014,428	$32,701,082	5.27%

Assume up front always $500,000 and 7.5% of total NPV to TeraLogic

Appendix G: Spreadsheet for Manufacturing Chips Alternative

MANUFACTURE CHIP OPTION

Price of Chip	**$10**						
Margin	**50%**						
Actual	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Model Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**
Quantity	0.00	0.00	631,408.29	1,081,135.16	1,722,924.83	2,411,023.25	2,683,478.84
Revenues	$0	$0	$6,314,083	$10,811,352	$17,229,248	$24,110,233	$26,834,788
Costs	$2,000,000	$0	$3,157,041	$5,405,676	$8,614,624	$12,055,116	$13,417,394
Profit	($2,000,000)	$0	$3,157,041	$5,405,676	$8,614,624	$12,055,116	$13,417,394
NPV	$9,812,582						

Summary	Chip Value	Choose Chip Alternative if can't get at least this royalty rate + $500K up front
BASE	$1,682,782	0.7%
LOW	($1,485,116)	
HIGH	$9,812,582	1.5%

Appendix H: Customers Quotations

Responses from Digital Camera Manufacturers:

OER Inc, Jeffery Gamble:

> *The driving reason for storage format selection "is the image file size. We need to store as many images as possible in as little space as possible."*

Phase One U.S. Digital Cameras, David Dentry, Support Manager

> *We are not satisfied with the performance of the JPEG format, so "we do not use any compression when capturing our 25-140MB images."*

Hasselblad, Lennart Stalfors, V.P., Digital Photography Division

> *"We are not entirely satisfied with JPEG. In particular we are interested in nondestructive compression algorithms for our future products"*

Kyocera, Inc., Garrett Beauvais, Sr. Planning & Research Consultant

> *"Our initial impressions (of wavelet) were that while the wavelet algorithms allowed for very efficient compression and small files sizes"*

Konica, Inc., Yoshitaka Ota

> *"JPEG is a standard format now. Unless another format has much better performance, we can not select it."*

Customer demand better image quality:

> *"As soon as a reasonably sharp, (greater than 600x600 true res.), is introduced for a reasonable price, (less than $200.00). Probably, be another year, maybe sooner."*

> *"I made up my own mind according to features and pic quality"*

> *"I don't want blocky pictures when I zoom"*

> *"A camera that offers more zooming capability."*

Appendix I: Uncertainties Existing in the Analysis

The major effect that would influence our analysis is the existing uncertainties in the digital camera market. The following is a summary of the potential uncertainties:

- ***Adoption of wavelet technology***

This is perhaps the most crucial uncertainty since it clearly affects the entire analysis. The JPEG format dominates the current still-picture market. In order to enable users to use the wavelet format, existing software and hardware tools must be extended to support wavelet technology. Such a shift in inertia may only be possible under the influence of strong consumer demand. History shows that it is not always the best technology that wins, as in the case of Sony's Beta video standard losing to the technologically inferior VHS format.

- ***Demand for wavelet digital camera***

As mentioned before, digital cameras are not yet mainstream consumer products; it is the rare photographic or technology enthusiast that buys them today. The demand for digital cameras greatly depends on public attitude towards its primary function: it could be viewed merely as a replacement for the traditional point-and-shoot camera; conversely, it could be viewed as a novel product with networking and display features. How market demand changes over time adds another layer of uncertainty to the analysis.

- ***Cost of manufacturing***

This uncertainty is specific to the alternative of making wavelet compression chips. The key drivers here are the costs of fabrication via third-party foundries and those associated with hiring additional staff to layout and design the chip. Marketing and distributing the product will also figure into the cost of this alternative.

- ***Sales Volume***

The number of wavelet related products sold depends on the alternative chosen. In a licensing arrangement, the number of licensees and the success of their products would determine volume. In a chip fabrication set-up, volume would be determined by the number and types of clients that buy the wavelet chip.

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