Overview and Main Features of *QuanTek*

(Revised October 25, 2017)

Robert Murray, Ph.D.
Omicron Research Institute

0.0 Contents

0.1 Introduction to QuanTek

QuanTek is a trading program for stocks (and indexes, mutual funds, futures, etc.) designed for short-term traders and long-term investors. The main feature of ***QuanTek*** is its use of an advanced **Wavelet Adaptive filter** to estimate **future returns**, and from these and the measured **covariance matrix** to compute an **Optimal Portfolio**. Then **short-term trading** takes

place by **portfolio rebalancing** within this portfolio. In this way ***QuanTek*** makes use of the most state-of-the-art principles of **Econometrics**, as well as **Digital Signal Processing**, available at the present time. ***QuanTek*** uses a modified **Markowitz** method to compute the **Optimal Portfolio**, which yields **maximum returns** with **minimum risk**. This is a modification of a standard computation from **Modern Portfolio Theory**. (See the article **Portfolio Optimization in *QuanTek***.)

It is well known that it is extremely difficult to "beat the market" by active trading. The **Random Walk** model is correct to a high degree of accuracy. However, as in any kind of market, in the stock market inefficiencies do exist which enable the astute trader to (potentially) make a profit. To make a profit in the stock market requires an accurate *estimate* of the **future returns** over some time interval. Unfortunately, these turn out to be extremely difficult to estimate. In many cases the best overall results can be obtained just by investing in an **index fund** or **ETF**. This is because, unless you are very careful, active trading can result in unacceptable **risk** (standard deviation of returns) without any corresponding gain in **returns**. ***QuanTek*** thus tries to combine the best of both worlds by using **active trading** within a **diversified portfolio**. The **Optimal Portfolio** is calculated every day, using the **Price Projection** from the **Adaptive filter** for each security, along with the measured **covariance matrix** between all the securities in the portfolio. Then the **short-term trading** consists of a **portfolio rebalancing** to bring the actual positions into line with the recommended positions every day. Using the **portfolio rebalancing** technique enables **short-term trading** while maintaining an **Optimal Portfolio** that **maximizes returns** and **minimizes risk**. Only in this way is it possible to see a slow, steady return over time in the portfolio, without too much variation in the returns, both in bull and bear markets.

At this point we would like to warn you that ***QuanTek*** is merely a *tool* to help you manage your portfolio for **maximum returns** with **minimum risk**. It is still of utmost importance for each investor or trader to *use his or her own judgment* in all investing or trading decisions. The ultimate responsibility for wise investing or trading rests with *you*, the investor or trader. The ***QuanTek*** program can help you optimize your portfolio more accurately, but ***QuanTek*** cannot supply all the information you need to make fully informed trading decisions. You should take into account the overall condition of the economy, as well as the health of various business sectors and the fundamental condition of each company you want to invest in.

It is only after these factors have been considered that you should engage in long-term investing or short-term trading in any particular company's stock. (This is also why ***QuanTek*** does not tell you *which* stocks to buy!) Even after this, you should always let your own judgment be the final criterion for each and every investing or trading decision. It is always unsafe to blindly trust the advice of any financial guru, broker, investment newsletter writer, as well as any software product, without subjecting it to your own critical examination and *making the final judgment yourself*!

0.2 How to Find Help in QuanTek

QuanTek is a complicated program, with many advanced features. In order to take advantage of its many features, an extensive **Help system** has been incorporated. This Help system consists of three parts. The first part is the regular **HTML Help file**, which is a compiled Help system similar to that found in many Windows programs. This Help file is accessible by clicking the **Help Topics** button on the Main Window or Graph Window toolbar. This is the button with the question mark icon. The Help file may also be accessed from the Help menu, or by pressing the **F1** key at any time. This Help file contains several articles (this one being the first in the list) explaining the theory behind ***QuanTek***, as well as individual **Help Topics** explaining how each feature of ***QuanTek*** works. The topics are listed in a Table of Contents on the left side, and displayed on the right. (In a future version we may replace this with an online Help system on the ***Omicron Research Institute*** website, www.omicronrsch.com.)

A second Help system consists of a set of **Help dialogs**. One of these, the **Welcome to *QuanTek*!** dialog, is displayed when the program first loads. It is a *modeless* dialog box with eight buttons. The fact that it is modeless means that you can leave it on the screen while using ***QuanTek***, moving it off to the side, if you wish. Or you can click **Exit Dialog** to close the dialog, then open it again from the **Welcome to *QuanTek*!** button on the **Main Window** toolbar. The eight buttons open eight other informational dialogs which are also modeless. Each of these explains a core topic about the operation of ***QuanTek***. At the bottom of each of these dialogs is a **Help Topics** button that links to the corresponding Topic in the main **Help** file. The **Getting Started** button at the bottom of the **Welcome to *QuanTek*!** dialog also links to a corresponding Topic in the main **Help** file.

The other button at the bottom of the **Welcome to *QuanTek*!** dialog, the **Statistical Tests** button, calls up the **Statistical Tests – LP Filters & Data** modeless dialog, which is also available from the **Main Window** toolbar. This dialog looks similar, with nine buttons, but each of these buttons actually calls up a **Statistical Test** dialog rather than a **Help** dialog. Each of these dialogs, however, contains a **Help Topics** button that links to the corresponding Topic in the main **Help** file. Each of these Statistical Tests Topics contains a detailed explanation of the corresponding Test, and you can also find an overview of the Statistical Tests in one of the articles at the top of the **Help** file. (See the article **Statistical Tests and Displays in *QuanTek***.)

A third *modeless* dialog, with eight buttons, is to be found in the **Graph Window** toolbar. It is the **Data Analysis – Graphs & Trading Rules** dialog. Each of the eight buttons links to an informational dialog that explains a core Topic of the Graph Window or the Statistical Tests associated with it. As before, at the bottom of each of these dialogs is a **Help Topics** button that links to the corresponding Topic in the main **Help** file. At the bottom of the **Data Analysis** dialog are two buttons, **Displays Help** and **Graph View Help**, which also link to the corresponding Topic in the main **Help** file. These modeless dialogs are intended to provide short summaries of important core Topics, and link to the main **Help** file in multiple ways for more detailed information.

There is also a second set of **Help dialogs**, that you can view by right-clicking in any window in ***QuanTek***. These are intended to provide a quick **Overview** of the corresponding window where the mouse was right-clicked. They also have a **Help Topics** button at the bottom, for more detailed information in the main **Help** file. Three of these **Overview** dialogs are also available from buttons on the **Dialog Bar**, because they talk about the **MainFrame Toolbar**, the **GraphFrame Toolbar**, and the **Dialog Bar** itself (where the right-click could not be implemented). These **Overview** dialogs are an additional supplement to the main **Help** file, somewhat similar to a Context Help system.

I implemented these redundant **Help** systems in the hope that it would make it easier for the ***QuanTek*** user to take notice of various features and figure out how to use them with a minimum of hassle. In particular, the two *modeless* Help dialogs were intended to provide a quick summary of the various features of ***QuanTek***, which you can then learn more about in the main **Help** file.

0.3 How to use QuanTek *for Trading*

The goal of ***QuanTek*** is to use the best ideas from the fields of **Econometrics** and **Portfolio Management** to devise a set of **Trading Rules** that yield the **maximum returns** with **minimum risk**. Unlike most other trading programs, we wish to place special emphasis on **controlling risk**. The **Random Walk** model is a close approximation to the stochastic properties of financial returns, viewed as a **stochastic process**. If this model were entirely correct, then no amount of **active trading** would result in positive returns over a long time average. This is because no matter what the previous price patterns might be, from any given point the probability for the price to go up or down from there is always exactly 50%. The only reason to invest at all would be if a **Random Walk with drift** model can be assumed, in which case the only sensible strategy would be Buy & Hold. Any active trading with this type of stochastic model would result in increased **risk**, with no corresponding increase in **returns**.

However, the assumption of a Random Walk with drift model is too simplistic and the actual market dynamics are far more complex. Rather than trying to estimate this (constant) long-term drift, we prefer to believe that it is possible to estimate this **expected return** on a variety of time scales, at least approximately. This is the purpose of the **Adaptive Linear Prediction filter**, which attempts to measure past **correlation** in the returns, which is usually **non-stationary** (time-dependent), and use this to estimate the future **expected return** on any chosen **Time Horizon**. The **average volatility** or **risk** along with the **correlation** between securities, or **covariance matrix**, is also measured, and together these quantities are used to compute an **Optimal Portfolio** using the modified **Markowitz** method. It should be emphasized that estimating the (time-varying) **expected future return** is a very difficult problem. In fact, the Random Walk model says it is impossible, and the expected return should be zero or, in the case of the Random Walk model with drift, the constant drift "velocity". However, it is essential to make this estimate in order to construct any kind of **Optimal Portfolio**.

The **Optimal Portfolio** is re-computed every day, after you have downloaded the end-of-day data for the securities in your portfolio. Then, on the next trading day, you can adjust or **rebalance** the positions in your chosen portfolio to correspond to the computed positions in the **Optimal Portfolio**. It does not matter exactly at what **buy/sell point** the adjustment is made, although using information in the **Stock Graph** and **Short-Term Trades** dialog, you can set **day limit orders** to try to get a better price. You can also use the **buy/sell signals** from the

Harmonic Oscillator indicator and a feature from the **Short-Term Trades** dialog to help you set ***N*-day limit orders**. However, the important point is to keep up with the changes in the recommended positions (either daily or on an *N*-day time scale), at whatever price. This is because the recommended positions in the **Optimal Portfolio** are responding to perceived **trend changes** on an *N*-day time scale, and it is these longer-term trends that are important. Another reason is that, according to the **Random Walk** model, it does not even matter at what price point trades are made, and this model is still approximately correct. Also, if the portfolio is kept in balance at all times, this is the best way to reduce **risk**, because no matter which way the market may move, the **short** positions will balance the downside risk and the **long** positions will take maximum advantage of the upside "risk", in a way that optimizes the **maximum return** with **minimum risk**.

The results of the **Optimal Portfolio** are displayed in the **Short-Term Trades** dialog, which can be displayed anywhere in the program by pressing the **Alt** key. A more detailed display of various portfolio information, including measured past and *estimated* future returns on four different time scales, as well as the **Optimal Portfolio** calculation, can be found in the **Portfolio Report**, which may be viewed anywhere in the program from a button on the **Dialog Bar**, as well as a toolbar button on the **Main Window** toolbar.

0.4 Stochastic Processes and Filtering

In the usual approach to **Technical Analysis**, such as described in the classic text by Edwards & Magee [EM] and the book by Pring [Pr], one looks for certain patterns in the past stock prices, which indicate potential **buy/sell points**. This is because these patterns in past prices are thought to be *correlated* with future up-trends or down-trends, either a change in trend from up to down or down to up, or a continuation of the current trend. These standard technical indicators are probably so well known by now that they are largely ineffective, since everyone follows them, and in addition they were more effective 50 to 80 years ago, when the markets were much smaller and much less *efficient* than they are now. So now the question is, since modern markets are very *efficient*, what is the best strategy for trading and investing, beyond **Technical Analysis**?

Financial markets are very efficient, but undoubtedly they are not *completely* efficient. It should still be possible to estimate that securities prices are overvalued or undervalued, and take

advantage of this determination to make a profit in the market. In other words, there should exist some **correlation** between **past price patterns** and **future returns**. The prices are, of course, influenced by *exogenous events* such as economic and political developments, as well as earnings reports from each company, which are largely unpredictable, but these may not affect the *long-term correlation* in the data. The correlation, if it exists at any given time, is due to the market dynamics not being perfectly *efficient*, because investors are not perfectly rational and knowledgeable in their behavior, and they also may have a short **time horizon**. The goal is to try to take advantage of this (slight) inefficiency by searching for the correlation and then base a set of **trading rules** on it. In order to find this correlation, we make use of an **Adaptive Linear Prediction** filter to make a **Price Projection**.

Pundits will say, of course, that there is no correlation in the stock data, and all the LP filter is doing is "fitting to the noise". It is indeed true that the market is very *efficient* and a large part of the **Price Projection** is indeed just that – fitting to the noise. Whatever correlation there is will be buried in stochastic noise and hard to isolate. However, it is necessary to try to make a prediction or estimate of **future returns**, no matter what, for the sake of **portfolio optimization**. So we assume that there is a *signal* buried within the *noise*, and try to make a prediction of the future *signal* apart from the *noise*. Hopefully the long-term estimate of future returns will "capture" the signal buried in the noise, although the shorter-term fluctuations may indeed just be "fitting to the noise". Note that *any* kind of estimate of future returns based on past data will run into this same type of problem, including **Technical Analysis** or **Fundamental Analysis**. Basing this estimate on long-term trends or moving averages, as in **Technical Analysis**, is equivalent to using a particular kind of LP filter, but the LP filters used by ***QuanTek*** are more sophisticated than that. The basic assumption being made here is that the *signal* resides in the low frequency, long-term changes in the returns, which is buried in the *noise*, which corresponds to the high frequency, short-term fluctuations in returns. On the other hand, there could very well be correlation in the high frequency fluctuations as well, which would require even higher-frequency data to resolve. The central problem, therefore, is one of separating out a *signal* buried in stochastic *noise*, and this is a problem in **Signal Processing**.

Stochastic Processes & Random Walk

Financial returns data constitute what is known as a **stochastic process**. The simplest type of stochastic process is the familiar **Random Walk**. It was first postulated over a century ago by Bachelier [B] that stock (actually, futures) prices follow a **Random Walk**. It is still hotly debated even now whether this is in fact the case. Many people, when performing a statistical analysis of stock data, are unable to discern any statistically significant difference between stock price series and a **Random Walk**. My position is that the stock prices are *not even* a **Random Walk**. A **Random Walk** (with drift) is a **stationary stochastic process**, meaning that the statistical properties do not change with time. In particular, if the price series were a **Random Walk**, then it would have a constant *drift velocity* or *secular trend*. In that case, the only sensible investment strategy would be **Buy & Hold**, to take advantage of this secular trend, which would always be constant. This is really quite a strong prediction of future price action! However, this is too good to be true, and evidently the constancy of this secular trend is too much to ask. Instead, it appears that price returns data constitute a **non-stationary stochastic process**. This means that the statistical properties vary with time, including the drift velocity or trend, and the correlation structure. So in this case, the optimal strategy is one of *active trading*. The purpose of the ***QuanTek*** program is to try to determine the optimum **Trading Rules** to take best advantage of this non-stationary correlation structure, using **portfolio rebalancing** within an **Optimal Portfolio**.

QuanTek has the capability to construct a variety of different technical indicators and measure the correlation between these and the *future returns*. The maximum length of the (daily) data set used is $N = 2048$ days, or about eight years. This means that there is a statistical uncertainty in the measurement of the correlation of about $1/\sqrt{N}$ or 2.21%. However, even a correlation of this magnitude could give a very nice annual gain if it were real, depending on the average daily volatility of the price returns. So this is the quandary: Small correlations, if they exist, can yield substantial profits from short-term trading, but these small correlations are buried in the *stochastic noise* and are of the same order of magnitude as the noise (or smaller). This is the reason why researchers in the past have not been able to discern any (statistically significant) difference between stock returns data and random (white) noise. Furthermore, the financial time series should be taken as a **non-stationary stochastic process**, so the correlation structure will

be time dependent. So the problem is how to extract useful non-stationary correlations from the stochastic noise and convert this correlation into profitable trading rules.

It should be mentioned that in the case of **stationary stochastic processes**, the *law of large numbers* is used to prove theorems about the existence and uncertainty of correlations. The correlation is only defined in the limit as the size *N* of the data set goes to infinity. For a **non-stationary stochastic process** we do not have this luxury. In fact, one major problem with financial time series is that the actual amount of data is rather sparse, so the statistical uncertainties are always large. If the correlation changes over an interval of *N* days, then the statistical uncertainty in the correlation will be $1/\sqrt{N}$ (approximately) and will never improve beyond that, no matter how long the data set is. So how can we ever prove the existence of correlation and the effectiveness of **Trading Rules**? Instead of the limit $N \to \infty$, which is usually used in the theory of **stationary stochastic processes**, we can in the present case substitute an average over a large portfolio of stocks. The **Adaptive Linear Prediction filter** is applied to the returns series of each individual stock, and it yields **Trading Rules** for that stock, which give a certain return per year. This return per year for an individual stock may be substantial, but the standard deviation of the return will also be substantial and will be of the same order of magnitude. However, if we keep applying the **Adaptive Linear Prediction filter** to the stock over a long period of time, the returns should be proportional to time *N*, while the standard deviation of returns only increases like $\sqrt{N}$. So eventually after a period of time, the average returns should become much greater than the uncertainty in returns. We can likewise reduce the standard deviation, relative to the returns, still further by computing the **Trading Rules** for an entire portfolio of stocks. The average **return** for the portfolio should remain roughly the same when the number of stocks is increased (for a given amount of equity), while the **standard deviation** of returns (**risk**) for the portfolio should decrease like $1/\sqrt{M}$ for a portfolio of *M* stocks (assuming the stocks are uncorrelated). More generally, it is given in terms of the **covariance matrix** for the portfolio. This is where the **Portfolio Optimization** routine in ***QuanTek*** comes in. The **return** for the whole portfolio is **maximized** while the **risk**, or **standard deviation** of returns, is **minimized**, subject to the degree of **risk tolerance** that you select. It is only by examining the whole portfolio return over a period of years that the effectiveness of the **Adaptive Linear Prediction filter** and **Trading Rules** can be evaluated.

Adaptive Linear Prediction Filter

Of central importance in ***QuanTek*** is the **Price Projection**. This is an actual estimate of the future prices based on an **Adaptive Linear Prediction filter**. Actually, this takes the form of an estimate of the **expected return**, given a **Time Horizon** for trading chosen by the user. Given the chosen **Time Horizon**, the **expected return** is optimized for this **Time Horizon** and displayed on the **Graph Window** as a straight line going out to 128 days in the future. But the chosen **Time Horizon** is displayed in the information bar at the top of the graph.

The **Adaptive filter** is calculated, when a data set of 2048 days is first downloaded, by starting at the beginning of the data and moving forward one day at a time, adapting the filter parameters to the data. Then, once this is finished, the filter parameters are saved in the data file. When a daily data update is downloaded, the **Adaptive filter** only needs to update the **Price Projection** for the latest data days, not the whole data set, which saves a lot of time. However, you can re-calculate the whole data set using a toolbar button on the **Graph Window**. Once the **Adaptive filter** is calculated, you can also toggle between it and the **Standard LP Filter** using a toolbar button, for comparison. Before the **Adaptive filter** is calculated, the **Standard LP filter** is the one that is displayed, since it is much quicker to compute (although it does not work as well).

The **Adaptive filter** is of the type known as a **Least-Mean Square (LMS) filter** [Hay]. This is a very basic type of adaptive filter, similar to but simpler than the **Kalman filter** [H]. In ***QuanTek*** it works by first defining a set of **regressors**, which we also call **technical indicators**, that are smoothed functions of the past data. These indicators start with the **Relative Price** indicator, the **Velocity** indicator, and the **Acceleration** indicator, and possibly others as well. These indicators are smoothed using **Wavelet smoothing**. This serves to eliminate stochastic noise and separate the indicator into various smoothing **time scales**. The **future returns** are then regressed on these indicators, a set of **LP coefficients** computed, and then these are used to compute a **Price Projection**. The **Price Projection** is then compared (in the past data) with the actual "future" returns, and an error signal generated, which is used to *adapt* the LP coefficients for the next iteration. In this way the **Adaptive filter** goes through a "training period", similar to a **Neural Network**. However, this is a *linear* filter, as opposed to the Neural Network, which is *non-linear*. But the indicator functions themselves can be highly non-linear, such as for example, **volatility**, which would lead to a variety of **GARCH** model (Generalized Auto-Regressive

Conditional Heteroskedasticity) [G]. So the **LMS** type of **Adaptive filter** is really a very general framework, and seems to work well for (noisy) financial data.

0.5 Graphs and Displays in QuanTek

QuanTek has a variety of graphs and displays. There is a **Main Graph**, which displays all the stock price data in a scrollable display. The **Main Graph** comes in four different **scales**, each of which displays a different aspect of the data. Also noteworthy is the **Price Projection** on the **Main Graph**, which shows the output of the **Adaptive Linear Prediction filter**. This filter *estimates* the future *N*-day return, where *N* is the chosen **Time Horizon**, and displays it as a straight trend-line out to 128 days in the future. Also displayed are **Bollinger Bands**, which give a visual display of the average volatility of the security.

Associated with the **Main Graph** are three other View windows. One is the **Harmonic Oscillator** splitter window, with three panes, which displays a set of custom **technical indicators** of the **oscillator** type based on **Wavelet** smoothing of the price data. Another is a **Stock Info** form view, which displays **split**, **dividend**, and (not used at present) **earnings** data, and also a variety of other **Fundamental** data. Finally, the **Stock Data** scrolling view displays the *actual* (unadjusted) prices, and also the **Adjustment factor**, which is the factor multiplying the unadjusted prices to get the **adjusted prices** (which are displayed on the **Main Graph**). This **Adjustment factor** compensates for **splits** and **dividends** in the (past) price data.

Corrected Prices & Scaling

It should be noted that the **Main Graph** displays the **corrected (log) price**, not the actual price. The latest prices are the actual prices, but the past prices have been *corrected for splits and dividends*. The correction is applied by computing an **Adjustment factor**, which is shown in the **Stock Data** scrolling view, along with the actual historical prices. The **corrected prices** should be viewed as a reflection of the *true value* of the security. This is because splits do not change the actual value of your position, although they change the price per share, because they also multiply the number of shares by the same factor as the share price was divided by. So correcting for past splits gives the prices that would have occurred in the past if the split had not occurred. Similarly, after a dividend is paid, the stock price will generally drop by the amount of the dividend, because the value of the stock has dropped by the amount of the dividend that was just paid out. So if the past (log) prices are corrected by a multiplicative factor to compensate for this

dividend, they represent the prices that would have occurred if there had been no dividend. The **Adaptive filter** and other technical indicators must use corrected prices to yield an accurate result. As stated, the true historical prices can be found by consulting the **Stock Data** scrolling view.

The **Main Graph** is (probably) unique in that it *preserves scale* for all securities on all scales. Thus the **expected return** can be seen at a glance from the *slope* of the graph, and the **volatility** can be seen at a glance from the length of the high-low (log) price difference and the **error bars**. The scale of the *slope* denoting the **expected return** is the same on all graphs and scales and can thus be directly compared, while the scale of the **volatility** is the same between different securities (on the same scale) and can also be directly compared between securities. Thus you can see at a glance which securities give the best returns and which are more volatile than the others. I regard this as a crucial feature of the ***QuanTek*** **Main Graph** view.

Main Graph – Overview

The **Main Graph** is designed to give a panoramic view of the entire data set, and is easy to interpret and easily scrollable. The price axis moves automatically to keep the display centered, when you scroll along the time axis, or you can scroll along the price axis manually if necessary. The prices are displayed on a logarithmic scale. There are four **scales** of the graph, each of which displays different information. The **Main Graph** displays *corrected* price bars for each trading day (adjusted for stock splits and dividends), showing **high**, **low**, **close**, and (on the highest scale) **open** prices. It also displays **buy/sell points**, **buy/sell signals**, and a **512-day smoothing curve**, ***N*-day smoothing curve**, **2048-day trend line**, and the highest scale is a **Candlestick chart**. In connection with the 512-day smoothing curves and 2048-day trend lines, a set of **Bollinger Bands** are displayed, corresponding to one- and two-standard deviations of the average absolute deviation of the prices from the curves. The **Price Projection** is displayed in blue, after the most recent past data on the graph. This display shows the output of the **Adaptive Linear Prediction filter**. At the top is an information bar which lists the ***N*-day expected return** (annualized) from the **Price Projection**. There is an error bar for each future projected price; to display an approximate *estimated* one-standard-deviation range for the future price. This range is equal to $\sqrt{n+1}$ times the average absolute deviation (volatility) of the (log) prices, where n is the number of days in the future for the projected price. (This corresponds to the

standard deviation of the **Random Walk** process.) The **relative (logarithmic) volume** is also displayed along the bottom of the graph.

When you open a stock data file, the **Main Graph** appears. This graph can be switched between four different magnification scales. These scales are denoted **scale 1, 2, 4,** and **8**, which indicates their relative magnification value. (Each scale is magnified by a factor of two relative to the preceding one. Both the horizontal and vertical axes are magnified by the same factor, so the slope of the price graph is preserved. This is a **logarithmic** slope, indicating the *percentage* change in prices per unit time.) When you first open the **Main Graph**, it is on **scale 2**. Each scale contains some different technical indicators, which are described here. You can move back and forth between scales using the blue arrows on the toolbar. You can also move back and forth between blocks of the data using the magenta arrows. (The whole data set, no matter how long up to 2048 days, is displayed in one continuous graph.)

On **scale 2** of the **Main Graph** are displayed the **buy/sell points**, denoted by green and red vertical arrows, which are the beginning points of a range of **buy/sell signals** that are displayed on **scales 4** and **8**. The **buy/sell signals** in the future **Price Projection** are set at prices offset from the expected price according to some multiple of the size of the error bar for day *N* in the future. (The multiple is set as one of the **Trading Parameters** in the **Trading & Portfolio** dialog.) These **buy/sell points** and **buy/sell signals**, derived from the **Harmonic Oscillator** indicator, may be used as *supplementary* **technical indicators** of the **oscillator** type to try to time trades according to possible cycles in the prices on time scale ***N***. We want to emphasize that there is no real way to test these signals for reliability and they may have no statistical significance. We advocate the **portfolio rebalancing** technique as the main mode of **short-term trading**. However, in the event you do not want to rebalance the portfolio every day, you may instead want to rebalance it ever *N* days on the average, timing your buys and sells in accordance with the **buy/sell points** and **buy/sell signals**. Another way to interpret these signals is that they represent possible ***N*-day trend changes**.

By the way, you can see all the graphs with either a black background or a white background, using the **Toggle Dark Colors** button on the **Main Window** toolbar. The black or white backgrounds use a different set of colors for the different features of the graphs. Generally, the colors for the black background are the *dark* versions of the colors for the white background. The black background is on by default. Lastly, one nice feature of the **Main**

Graph is that, if you rest the mouse pointer at any point in the graph, a **tool tip** pops up, which lists the price level at that point and the date. This is very handy for finding the price and date of any point on the graph. You can also display a horizontal line at any price point just by clicking the mouse at that point, or by using the toolbar buttons.

Main Graph – Scale 1

This is the long-term view of the stock data. Each day of data occupies one pixel of the screen, so there is no tick for the closing price on this scale. The future projection, with error bars, is the blue area to the right of the graph. On this scale, a **2048-day trend line** (or the length of the data, whichever is shorter) is displayed which is a **robust straight-line** fit to the data (minimizing the sum of the absolute deviations from the line). This is shown as the centerline, in dark yellow. On either side of this line are two sets of **Bollinger Bands**, at one standard deviation (dark cyan) and two standard deviations (dark magenta) away from the centerline, respectively. These may be used to gauge the relative long-term variations of the (corrected, log) price away from the long-term robust trend line – an **overbought/oversold** indicator. This graph is good for seeing the long-term trend of the price data at a glance. Also, in the **Buy & Hold** method of investing, the **2048-day trend line** is the indicator you would use to estimate the **long-term future returns**. In fact, for large well-established companies on an established trend we have found that this indicator has a robust correlation with future returns. (But beware that the trend can change with changes in the economy.)

Main Graph – Scale 2

This is the scale which first appears when a stock data file is opened. On this scale, there are two pixels per trading day. Each vertical bar ranges between the high and low for the day, and there is a horizontal tick for the closing price. If you look closely, underneath the data bars is a dark blue curve, representing the *N*-day (acausal) smoothing curve of the price data, where *N* is the **Time Horizon** that you have selected (in the **Trading & Portfolio Parameters** dialog box). To the right is the **Price Projection**, which is the output of the **Adaptive Linear Prediction filter**, and the vertical blue bars are the one standard deviation error bars for the projection. By analogy with the *Random Walk*, they can be seen to grow approximately as the square root of the number of days in the future. The dark yellow curve is a 512-day (acausal) smoothing of the price data. On either side of this curve, in dark cyan and dark magenta, are the

Bollinger Bands corresponding to one and two standard deviations, respectively, away from the center curve.

Featured prominently in this scale are the **buy/sell points**, which are the green and red arrows. These show the optimum points to buy and sell, given the selected **Time Horizon**, and correspond to the positive/negative going zero crossing points of the **Velocity** indicator (on the middle pane of the **Harmonic Oscillator** splitter window). These green and red arrows are represented in all the splitter windows as green and red vertical lines, and they serve to line up all the features on the graphs, as well as indicate the optimum *past* ***N*-day buy/sell points**. The green and red arrows in the future **Price Projection** are *future estimated* **buy/sell points**, based on the **Harmonic Oscillator** indicator.

Main Graph – Scale 4

This graph is basically the same as **scale 2**, except a factor of two larger. There are four pixels per data point on this scale. This makes it easier to see the short-term price fluctuations. The main difference from **scale 2** is that, instead of displaying the **buy/sell points**, it displays the **buy/sell signals**. The **buy/sell signals** are ranges of buy points and sell points, designed for setting limit orders, with the starting point in each range of **buy/sell *signals*** marked as the **buy/sell *point***. The absolute value of the **Velocity** indicator above which a set of **buy/sell *signals*** starts, marked by a **buy/sell *point***, is set by the **Threshold** control on the **Trading & Portfolio Parameters** dialog. It will be noticed that the buy signals are a little below the *N*-day smoothing of the prices, and the sell points a little above. The degree that the **buy/sell signals** are below/above this *N*-day smoothing curve is set by the **Range** control on the **Trading & Portfolio Parameters** dialog. As just stated, the **buy/sell signals** in the future **Price Projection** may be used as a guide for placing optimal ***N*-day buy/sell limit orders**.

Main Graph – Scale 8

This is the largest scale of the four graph scales. This scale uses eight pixels for each day of data. It will be noticed that this scale incorporates **Candlestick Charting** rather than the more usual bar charting of the other scales. The **Candlesticks** provide a way to display the **high**, **low**, **close**, and **open** prices, whereas with the bar charting the open price is not displayed. The **Candlestick** consists of a colored rectangle superimposed on a vertical line. The ends of the vertical line mark the high and low (log) prices for the day, as before. However, the upper/lower

edges of the rectangle mark the open/close or the close/open prices. If the close is higher than the open (an *up* day), the rectangle is colored sky blue, while if the close is lower than the open (a *down* day) the rectangle is colored dark blue. There is a whole set of technical patterns associated with and unique to the **Candlesticks**, which can be found in books devoted to **Candlestick Charts** (see also an appendix to Pring's book on **Technical Analysis** [Pr]). Also displayed on this scale are the **buy/sell signals**, displayed as little green/red triangles. All the other features of the graph, such as **Bollinger Bands**, are the same as with the other scales (except that the *N*-day smoothing curve is not shown on this scale). This is the best scale to use to study the price action for each individual day.

Harmonic Oscillator Splitter Window

The **Harmonic Oscillator** is a set of three **technical indicators** in a splitter window, obtained by three different smoothings of the price data using the *acausal* **Wavelet smoothing filter**. From these three smoothings, a set of **buy/sell points** are shown as vertical green/red lines in each window. The *present time* is displayed as a vertical yellow line. To the *past* of this line, the past data are smoothed, and **buy/sell points** are displayed *with the benefit of hindsight*. To the *future* of this line, a **future projection** is displayed (based on *past* data), and future *estimated* **buy/sell points** are also shown. This **future projection** (of the indicators) is based on the **Standard (Burg) Linear Prediction filter**, different from the **Price Projection** used in the **Main Graph**. (The **Standard LP filter** is like an extrapolation of the sinusoidal components of the signal, which makes it the best choice for this particular indicator.)

The panes of this splitter window are called **Relative Price**, **Velocity**, and **Acceleration**. These three indicators display a smoothed *difference* of prices between an *N*-day and 512-day smoothing, a smoothed *first derivative* or *returns*, and a smoothed *second derivative* or rate of change of returns, respectively. Using *acausal* **Wavelet smoothing**, so that there is no lag or phase shift, the **buy/sell points** should line up with the minima/maxima (**min/max**) of the **Relative Price**, the positive/negative zero-crossing (**Z+/Z–**) of the **Velocity**, and the maxima/minima (**max/min**) of the **Acceleration**, respectively. The **buy/sell points** derived from the **Harmonic Oscillator** indicators are shown in all the splitter windows as green/red vertical lines, and the **Main Graph** as green/red arrows.

Harmonic Oscillator Buy/Sell Signals

The **buy/sell signals** are defined from the three **Harmonic Oscillator** indicators. A **buy signal** is triggered if the **Relative Price** indicator is negative and the **Velocity** indicator is above a certain level set by the **Threshold** control in the **Trading & Portfolio Parameters** dialog. These last two conditions restrict the range of buy signals to the quarter "cycle" (if the data were sinusoidal) following the minimum of the **Relative Price** indicator. A **sell signal** is triggered if the **Relative Price** indicator is positive and the **Velocity** indicator is above (in absolute value) a certain level set by the **Threshold** control in the **Trading & Portfolio Parameters** dialog. These last two conditions restrict the range of sell signals to the quarter "cycle" (if the data were sinusoidal) following the maximum of the **Relative Price** indicator. The **Threshold** control determines the minimum level (in absolute value) of the **Velocity** indicator at which **buy/sell signals** are triggered. The **Range** control determines the range of the daily average **volatility** (in the **Price Projection**) that triggers the future **buy/sell signal**. In this way you can set **buy/sell signals** only for extremes of price, or more often for smaller maxima or minima of price. The **buy/sell signals** are displayed in **scale 4** and **scale 8** of the **Main Graph**.

The **buy/sell points** consist of the first of a series of **buy/sell signals**. Hence a **buy point** will occur when the **Relative Price** indicator is at a minimum (**min**), the **Velocity** indicator is crossing the zero line moving upward (**Z+**), and the **Acceleration** indicator is at a maximum (**max**). A **sell point** will occur when the **Relative Price** indicator is at a maximum (**max**), the **Velocity** indicator is crossing the zero line moving downward (**Z–**), and the **Acceleration** indicator is at a minimum (**min**). Actually these points will be delayed a little bit according to the minimum **Threshold** setting. These **buy/sell points** are mainly for the purpose of marking the most favorable points to buy and sell in the range of **buy/sell signals**, and also as markers to line up the features in all the graphs.

Other Stock Graph Features

It should also be mentioned that the **logarithmic volume** appears at the bottom of each graph, relative to the *mean* value of the logarithmic volume. You can also display a horizontal line anywhere in the graph simply by pointing the mouse to that price level and left-clicking. You can draw a horizontal line for a given price level using the **Horizontal Line** button on the toolbar. You can also insert an **exponential Moving Average** (of the prices relative to the 512-

day smoothing curve) using the **Moving Averages** toolbar button. You can select a color for the horizontal line or exponential MA by using the **Custom Colors** button. Finally, you can toggle the **buy/sell points** and **buy/sell signals** on and off using the **Buy/Sell Points** button. You can view the appearance of the **Price Projection** at any date in the past using the **Historical Projection** button. You can calculate the *actual* **error bars** (over the past 1024 days) and display them using the **Projected Error Bars** button. Using this button you can also toggle between the *estimated* **error bars** and the *actual* **error bars** (after they are calculated). Finally, you can restore the graph to its default appearance using the **Restore Data** button.

0.6 Portfolio Optimization in QuanTek

The **Portfolio Optimization** routine makes use of a modified version of the standard **Markowitz Model** from **Modern Portfolio Theory**. (See the article **Portfolio Optimization in *QuanTek***.) This calculation uses the **covariance matrix** of all the stocks in the **portfolio**, along with the **expected returns** computed from the **Price Projection**, to compute an **Optimal Portfolio** that **maximizes returns** and **minimizes risk** for the overall portfolio.

Optimal Portfolio

The **Portfolio Optimization** routine computes the **covariance** matrix of all the stocks in the **portfolio**, consisting of all the *stocks* (not *indexes* or *averages*) in a particular folder that have the "**Trade this stock?**" checkbox checked (**Buy/Sell** button on the **Dialog Bar**). The **variance** and **covariance** are based on the average **volatility** and **correlation** of the returns between all the stocks. The **variance** (actually, **standard deviation**, the square root of **variance**) of returns of an individual stock is a measure of its **risk**. The other quantity that goes into the calculation is the **expected return**, which is estimated using the *N*-day future return from the **Price Projection**. Then a calculation is done to **maximize returns** for the portfolio as a whole, and at the same time **minimize risk**. This calculation is a modified version of the standard **Markowitz Model**. This results in an **optimal portfolio** in which the recommended positions optimize the ratio of **return/risk** for the whole portfolio. (The ratio of **return/risk** for each security individually is called the **Sharpe Ratio**.) This calculation depends on a parameter called the **Risk Tolerance** (opposite of **risk aversion**), which you set in the **Trading & Portfolio Parameters** dialog box. The other parameter you need to set is the desired **Margin Leverage**, which sets the overall ratio of the value of the portfolio to the equity of the portfolio (in the

Model Portfolio tracked by ***QuanTek***). The results of this calculation are displayed in the **Short-Term Trades** dialog and in the **Portfolio Report**.

Short-Term Trades Dialog

The **Short-Term Trades** dialog is a *modeless* dialog box, which can be viewed from anywhere in the ***QuanTek*** program just by pressing the **Alt** key, or using the **Short-Term Trades Dlg** toolbar button. It displays all the most important trading information for the whole **portfolio** of stocks together in one place, to enable daily **portfolio rebalancing** at a glance. In the main list box of this dialog, each security is displayed on one line. (You can open each stock data file by double clicking on this line.) The line of information starts with the **symbol** and **actual number of shares** currently held, and the corresponding **percentage** of the portfolio. Then the output from the **Portfolio Optimization** routine is shown, which consists of the **recommended number of shares** in the **portfolio** and the corresponding **percentage** of the portfolio. Finally the **Sharpe Ratio** is displayed, which is the ratio of the ***N*-day expected return** to the **average risk (standard deviation)**. This gives an indication of the "quality" of the position, with a higher value either long (positive) or short (negative) indicating a higher **return/risk** ratio.

On the right-hand side of the **Short-Term Trades** dialog, there is a list box containing a column of prices on the left and a column of percentages on the right. In the center (vertically) of the list box, corresponding to ZERO percent, the price listed is the **estimated *N*-day closing price**. This estimate is based on the estimate of the *N*-day return from the **Price Projection**. By clicking on one of the prices in the list box (representing the possible *N*-day prices), it is brought to the center, and then the *difference between the selected price and the estimated N-day closing price as a percentage of N-day volatility* can be read from the right-hand column. Each trader can then use this to set ***N*-day limit orders**, according to *N*-day price changes as a percent of *N*-day volatility. This is the most versatile way we could think of to accommodate a wide range of ***N*-day trading strategies**.

Portfolio Report

The **Portfolio Report** contains all of the information in the **Short-Term Trades** dialog, and more besides. You can create a **Portfolio Report** just by clicking the button on the **Dialog Bar**, or the toolbar button on the **Main Frame** toolbar. Then the portfolio information is

acquired from the header files of all the securities in the selected folder, or **Stock Group**, and the report is then compiled.

The first part of the **Portfolio Report** consists of a list of all the securities in the **Stock Group**, together with information such as the ***N*-Day Expected**, ***N*-Day Return**, **128-day Return**, **2048-day Return**, and the **Standard Deviation**. The ***N*-Day Expected** is the *estimated* *N*-day **future return** from the **Price Projection**. The ***N*-Day Return** is the *N*-day return over the past *N* days. The **128-day Return** is a wavelet-smoothed average of past returns with time scale of 128 days, and the **2048-day Return** is the slope of the **2048-day robust trend line**. The ***N*-Day Expected** and the **Standard Deviation** are just the information that goes into the **Optimal Portfolio** calculation.

Next is a section consisting of a list of all the securities actually owned in the portfolio, together with the **number of shares**, **market value**, **last price**, and **basis price**. The **basis price** is updated every time a security is bought or sold.

Then is a list of the overall portfolio quantities of interest, such as the **account equity**, **long and short market value**, **cash balance**, and **buying power**. Also the **margin leverage** is displayed, which is the long market value plus short market value, as a percentage of account equity. (Note that the **account equity** is the long market value minus short market value plus cash balance. When you add to or subtract from a long or short position, the account equity remains unchanged.)

After that is a section listing the **Optimal Portfolio** calculation, listing the **Current Position (shares)**, **Current Position (percent of equity)** and then the **Optimal Position (shares)**, **Optimal Position (percent of equity)**. Finally is displayed the **Sharpe Ratio**, which is the ***N*-Day Expected** return (annualized) divided by the **Standard Deviation**, expressed as a percent. This quantity is a measure of the ratio of **return/risk** for the individual security.

Finally, the **Optimal Portfolio** calculation yields the **Portfolio Margin Leverage** (given by the chosen **Margin Leverage** setting), the **Portfolio (*N*-day, annualized) Expected Return**, and the **Portfolio Standard Deviation**. This calculation then gives you an estimate of the overall (*N*-day) performance of the **Optimal Portfolio**. (Note that the accuracy of the **Portfolio Expected Return** depends on the accuracy of the ***N*-day Price Projection**.)

0.7 Trading and Portfolio Parameters Settings

There are two groups of slider bars in the **Trading & Portfolio Parameters** dialog box. These control the settings for the **buy/sell signals** and the **portfolio optimization** calculation. At the bottom of this dialog box is a list box to set the **Time Horizon** for trading, which sets the time scale for optimization of the **Price Projection** as well as smoothing of the **Harmonic Oscillator** and the **buy/sell signals** and **points**.

Time Horizon for Trading

This is a list box for setting the **Time Horizon**, which controls the time scale for optimization of the **Price Projection** as well as smoothing of the **Harmonic Oscillator** indicators and the resulting **buy/sell signals** and **points**. It also controls the time scale of the *N*-day smoothing curve shown on the **Main Graph**. The possible values of the **Time Horizon** are from 1 to 128 days, and this should be thought of as the typical holding period for short-term trading.

Trading Parameters

The left-hand group of two slider bars controls the display of the **buy/sell signals**. These **buy/sell signals** are displayed on **scale 4** and **scale 8** of the **Main Graph**. (The beginning points of each set of **buy/sell signals** are called **buy/sell points** and are displayed on **scale 2** of the **Main Graph**.)

Threshold: This slider bar controls the minimum absolute value of the **Velocity** indicator (annualized return) above which the **buy/sell signals** can be triggered. On its lowest setting of 20%, the **Velocity** indicator must have an annualized value of at least 20% gain or loss per year before the **buy** or **sell signals** can be triggered. This limits the threshold of the expected future trend at which the **buy** or **sell signals** are triggered. On its highest setting of 0%, the **buy/sell signals** are triggered right on the zero-crossings of the **Velocity** indicator. So there will be less trading on the lower settings, and more trading on the higher settings.

Range: This slider bar controls the **limit price** of the **buy/sell signals** displayed on the **Main Graph**, as a percentage of the **average absolute deviation** of the daily prices (average range of highs/lows relative to the average intra-day price). This range is relative to the **N-day smoothing curve** on the **Main Graph**. For the future **Price Projection**, the range is the

percentage of the **average expected N-day absolute deviation**, as indicated by the **error bars** in the future **Price Projection**. On the lowest setting of 200%, the **buy/sell signals** appear at a distance of 200% of the **average (expected) absolute deviation** from the *N*-day smoothing curve. On the highest setting of 0%, the **buy/sell signals** appear right on the *N*-day smoothing curve. So there will be less trading on the lower settings, and more trading on the higher settings.

Portfolio Parameters

The right-hand group of two slider bars controls the settings for the **Portfolio Optimization** calculation. This calculation uses the estimated future **expected return** and the measured past volatility or **risk** (for each stock in the portfolio) to compute an **Optimal Portfolio** that *maximizes returns* and *minimizes risk*.

Margin Leverage: This specifies the (average) margin leverage that you want for the whole portfolio, given the total equity. By margin leverage, we mean the amount of money invested in the portfolio as a fraction of the equity. Then the optimal number of shares of each stock is computed based on the chosen margin leverage. The range of the **margin leverage** settings is from 0% to 200%, corresponding to the allowed range in a typical margin account. So the higher the setting is, the more aggressive the trading in the account.

Risk Tolerance: This is the other parameter in the **Portfolio Optimization** calculation. In order to know what relative weight to give to the **expected return** versus the **risk**, the portfolio optimization routine needs to know your degree of **risk aversion**. The opposite of this is your **risk tolerance**, which is your willingness to tolerate **risk** for the sake of greater **returns**. Setting the slider on "min" results in the least possible variance in the total portfolio return (**risk**), at the expense of the mean value of the return (**expected returns**). Setting the slider on "max" basically results in the variance of returns (**risk**) being ignored, and the proportion of the portfolio invested in each stock is essentially proportional to the **expected returns** alone (relative to the other stocks in the portfolio). So the higher the setting is, the more aggressive the trading in the account.

0.8 Other Features in QuanTek

These are the most important features of ***QuanTek***. There are many other features as well. The actual prices are displayed in list form in the **Stock Data** scrolling window. Some useful **Fundamental Data** are displayed in the **Stock Info** form view. The list of stocks, indexes,

and other types of files in the currently active **Stock Group** are shown to the left side of the **Main Window** in the **Portfolio dialog bar**. Double clicking on any one of these entries is a quick way to open that data file. The **Portfolio dialog bar** is a *docking* control bar. This means you can detach it and dock it anywhere in the **Main Window**. To return it to its standard docked position, use the **Show/Hide Portfolio Bar** toolbar button on the far left. You can also open and edit either a **Report (*.rtf)** or a **Text (*.csv)** file using toolbar buttons on the **Main Window**. The **(*.rtf)** format is used for Report files, and the **(*.csv)** format is used for data downloads. You can set a timer for automatic daily data download using the **Daily Auto-Download Time** dialog. You can update **intra-day** or **end-of-day** data using the **Intra-Day Data Update** toolbar button. You can update **Fundamental** data using the **Fundamental Data** toolbar button. You can update the **Model Portfolio** and view its status using the **Portfolio and Asset Data Dialog**. Finally you can switch between **black** and **white** background for all graphs and displays, using the **Toggle Dark Colors** toolbar button on the **Main Window**. The **black** is on by default.

0.9 References

[B] Louis Bachelier, Théorie de la Spéculation (doctorial dissertation), *Annales Scientifiques de l'Éciole Normale Supérieure* (iii), Vol.17, pp.21-86 (1900) Translation: Cootner (1964)

[BD] Peter J. Brockwell & Richard A. Davis, Time Series: Theory and Methods, 2nd ed. Springer-Verlag, New York (1991)

[EM] Robert D. Edwards & John Magee, Technical Analysis of Stock Trends, John Magee Inc. (1992)

[FFK] Frank J. Fabozzi, Sergio M. Focardi, & Petter N. Kolm, Financial Modeling of the Equity Market: From CAPM to Cointegration, John Wiley & Sons, Hoboken, New Jersey (2006)

[G] Christian Gourieroux, ARCH Models and Financial Applications, Springer-Verlag, New York (1997)

[H] Andrew C. Harvey, Forecasting, structural time series models and the Kalman filter, Cambridge University Press (1989)

[Hay] Simon Haykin, Adaptive Filter Theory, 4th ed., Prentice Hall, Upper Saddle River, NJ (2002)

[Pt1] Edgar E. Peters, Chaos and Order in the Capital Markets,
John Wiley & Sons, New York (1991)

[Pt2] Edgar E. Peters, Fractal Market Analysis,
John Wiley & Sons, New York (1994)

[Pr] Martin J. Pring, Technical Analysis Explained, 3rd ed.,
McGraw-Hill, New York (1991)

[NR] William H. Press, Saul A. Teukolsky, William T. Vetterling, & Brian Flannery,
Numerical Recipes in C: The Art of Scientific Computing, 2nd ed.,
Cambridge University Press (1992)