would need to contact their appropriate supervisor and make arrangements for having their models validated for regulatory capital purposes.

*Modelling Market Risk*

In order to measure exposures when evaluating trading risks, many institutions calculate the ''value-at-risk'' (VAR), representing the maximum amount by which the market value of their trading portfolios could decline during a specific period of time and with a certain degree of statistical confidence. For example, at the close of business on day one a bank might calculate its VAR to be $10 million, indicating that it has only some small chance of losing more than that amount on its existing holdings, if they were held through the end of day two. Most institutions use this measure as a management tool for evaluating their trading positions, limits, and strategies. By measuring the risk daily, management can quickly revise its positions, limits and strategies as market conditions change.

A value-at-risk model requires a variety of inputs: (1) Accurate and timely information about the institution's trading positions, (2) information about past movements of relevant market prices and rates, and (3) several key measurement parameters, such as the length of the historical period for which market changes are observed (observation period), management's required level of confidence, and the assumed holding period for which the value of current trading positions may change. When evaluating their current positions and estimating future market volatility, institutions typically use a series of ''market risk factors'' that they have determined affect the value of their positions and the risks to which they are exposed. These factors, in turn, can be grouped into four categories, depending on the nature of the underlying risk: interest rates, exchange rates, and equity and commodity prices, with related options volatilities included in each risk factor category.

Having determined which risk factors to use, an institution estimates the potential future volatility of the factors. Most often this calculation is based on the past movements of these factors over some specified time horizon, with some institutions using long historical time periods and others focusing on more recent market behavior. However derived, the estimates of potential market movements are combined with current position data to calculate an estimate of the potential loss that may arise from those positions for a specified holding period. Just as institutions use different historical time periods when computing possible changes in market risk factors, they also use different confidence levels to estimate potential losses. Some institutions use a 90 or 95 percent confidence level (one-tail), while others use a higher level of statistical confidence.

Institutions also use different modelling procedures in calculating their market risk exposures. The most common models are based upon variance/covariance methodologies, historical simulations, or Monte Carlo simulation techniques. In the case of the variance/covariance approach, the change in value of the portfolio is calculated by combining the risk factor sensitivities of the individual positions—derived from valuation models—with a variance/covariance matrix based on risk factor volatilities and correlations. An institution would calculate the volatilities and correlations of the risk factors on the basis of the holding period and the observation period. Value-at-risk is determined according to the desired level of statistical confidence.

Using historical simulations, an institution would calculate the hypothetical change in value of the current portfolio in the light of actual historical movements in risk factors. This calculation is done for each of the defined holding periods over a given historical measurement horizon to arrive at a range of simulated profits and losses, and the confidence level, again, determines the value-at-risk.

Monte Carlo techniques also consider historical movements, but only to determine the probability of particular price and rate changes. Using these probabilities, the institution would then construct a large number of theoretical movements to evaluate the range of its portfolio's potential market values and identify the maximum loss consistent with the necessary confidence level.

*Proposed Modelling Constraints*

The Agencies recognize that institutions have adopted different assumptions and measurement techniques in their internal market risk models and that such differences often reflect distinct business strategies and approaches to risk management. In developing a framework for the use of internal models for regulatory capital purposes, the Agencies believe that some constraints should be placed on model parameters and assumptions. Such restrictions would help to ensure that prudential capital levels are maintained and that institutions with similar risk exposures have similar capital requirements.

Since institutions use VAR to guide them in setting trading limits, rather than for evaluating capital adequacy, they set their model parameters to address normal conditions. Indeed, the models are designed to ensure that actual trading results often exceed the projected levels so that management is better able to evaluate the model's predictive accuracy and to respond to events that generate unexpectedly large gains or losses. During a given year, for example, a model based on a 90 percent confidence level (one tail) could be expected to underestimate actual trading losses more than 20 times.

Moreover, knowing that a day's trading results could be expected to exceed the VAR ten percent, five percent, or even only one percent of the time, says nothing about the *magnitude* by which the VAR might be exceeded. The probabilities of VAR models cannot be extended to estimate the size of a highly unlikely event because most models assume that market movements are distributed normally. While that assumption may be adequate for a model's intended purpose, it permits the model to greatly understate the likelihood of a large loss. For example, assuming a normal distribution, the likelihood of experiencing a four standard deviation event is approximately 3 in 100,000—in trading terms, about once in 130 years. In practice, however, such unusual market movements are seen in most major markets on average almost every year.[7]

These conditions require that regulators impose some constraints or other adjustments to the VAR figure that each institution derives in order to provide the rigor and consistency that a capital requirement demands. At the same time, the Agencies want to minimize the costs and dislocations to an internal modelling system that external constraints could create and have sought to balance these conflicting objectives through a combination of qualitative and quantitative constraints.

*Qualitative Standards*

The qualitative standards are designed to ensure that institutions using internal models have market risk management systems that are conceptually sound and implemented

[7] Daily rate or price movements of a half-dozen major currencies and U.S. Treasury maturities and of several U.S. equity indices each moved by at least four standard deviations on average about once a year during the period 1977–1994. The drop in the value of the S&P 500 index on October 19, 1987 represented a 20 standard deviation event in terms of daily price movements.