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Session 3PD
Asset Modeling Concepts

Moderator: Frederick R. Jackson
Panelists: Teri Geske

Summary: How rigorous are your asset/modeling techniques? What systems do you use? Do investment experts contribute to or audit your process? How demanding are state regulators who review your processes? Are your modeling processes focused on exclusively satisfying regulatory solvency issues, or does your asset/modeling also contribute to management-focused asset/liability modeling (ALM) work affecting strategic business decisions?

MR. FREDERICK R. JACKSON: Teri Geske is from Capital Management Sciences, a leading provider of fixed-income portfolio analytics. Many of you might be familiar with the BondEdge system from CMS. She's the senior vice president in charge of product development and is a frequent speaker at SOA meetings. After Teri, I will speak. We've tried to dovetail our presentations. I will try to come up with some specific examples to address her concepts.

MS. TERI GESKE: My topic is Asset Modeling Concepts Focus on Risk. Let's discuss asset models and how we live with uncertainty. That's specifically with respect to modeling fixed-income securities because that's what I know best, but with most, if not all asset classes, there's a good deal of uncertainty associated with attempting to model them. What I'm going to spend a good portion of the presentation talking about is this concept of model risk. You can define model risk as the potential for error due to modeling limitations and/or assumptions in your model that are either imprecise or that simply don't hold up under extreme market conditions. That is different than what I would call market risk or credit risk. Market risk is probably best

defined as the risk of loss due to a change in interest rates, commodity prices, exchange rates, equity prices or some other change in the market that causes your assets to lose value. Credit risk is the risk of loss due to a default of a particular creditor, or a downgrade which causes the value of a creditor's debt to fall. One way of thinking about model risk versus market or credit risk is to think about the folks at Long-Term Capital Management (LTCM). We're all familiar with who they are and what happened to them.

There was a recent article in *The Wall Street Journal* about a book someone has written about LTCM. First, I'm not endorsing this book. I frankly think it sounds a little bit sensationalistic, but there were some points in the article that I thought really illustrated this concept quite well. It pointed out that during the Fall of 1998, when Long-term Capital Management suffered this crisis that almost brought down the financial system, there were things happening in the market that the traders at LTCM had never seen. Therefore, their models didn't incorporate these kinds of risks. So it wasn't that their models were wrong; their models could have been mathematically precise, but the parameters they fed into the models just didn't capture what was happening in the marketplace. In this article, the author said, "The traders hadn't ever seen a move like that and, true, it had happened in 1987, but Long-Term Capital's models didn't go back that far." Note that they had calculated, with mathematical certainty, that it was extremely unlikely that they would lose more than $35 million on any single day. Then, in one day, their assets dropped $553 million. That gives you a sense of the magnitude of the model risk. The company's models were inaccurate due to assumptions that didn't hold up under extreme market conditions. That was a rather extreme case of model risk.

What really matters in types of model risk? I really pose the question that way because I think it's a useful device for you in evaluating the models that you're using. What assumptions matter to the answer your model supplies? With your liability models, there are things like your unscheduled withdrawal assumptions and crediting rates. All of those are uncertain things that go into your liability models. If you're incorrect or imprecise about them, it will have a big impact on the results.

What matters in asset models is anything that affects the probability or the timing or the amount of the cash flows you expect to receive, or the discount rates that you use to compute the present value of those cash flows. With fixed-income securities, there are also things like capturing the path-dependency of certain cash flows, which I'll talk about. There are prepayment models that affect the amount and the timing of cash flows. There are volatility estimates that affect the likelihood that an option embedded in the securities will be exercised and these are things that I'll talk about with respect to fixed-income asset modeling.

There are other asset modeling problems such as value-at-risk. Value-at-risk makes assumptions about correlations that might or might not hold. These assumptions about correlations would be something you'd want to look at.

Model risk has a ripple effect through just about everything you do. It affects the valuation of your assets, so any time you try to come up with the market value of a portfolio, you have some model risk. Any time you try to do a relative value analysis to find out if one security is better than another security, you have model risk. In risk management, you compute effective duration, or the price sensitivity of a fixed-income security to a change in interest rates, and that has an element of model risk to it. When you're setting exposure limits, if you tell a portfolio manager that he can't hold more than this amount in this sector or can't have durations higher than this or lower than that, you have model risk.

In doing any sort of forecasting, you'll do cash-flow projections, total return simulations, horizon analyses, and earnings forecasts. You have model risk in all of those things. In attribution analysis, you're trying to figure out where your return came from after the fact, so that you can decide whether your managers have done a good job or whether you understand where your bets were in your investment portfolio. You're trying to allocate your return to various sources of risk. There's a lot of model risk and model uncertainty that goes into that.

Valuation, risk management, forecasts and attribution are garden variety, everyday model risks. In more extreme cases, you'll see mark-to-model risks. Even though your model might be as good as it can get as far as modeling is concerned, there can be extreme market moves that no

model can anticipate. Therefore, all models get blown out of the water, and I really think the only way you can address that concern is to do extreme stress tests on the assumptions in a model and see what happens to the result. If the result is that your firm is out of business, then you really have to examine whether or not your portfolio risks are acceptable. I guess one illustration of that would be in 1998 when credit spreads on bonds moved 40 basis points in the course of a couple of days. In hindsight, and with all the Monday morning quarterbacking going on, people said, well, that was a five or six standard deviation move. You are statisticians; you understand math much better than I do. A six standard deviation move happens about once every billion years. You could say it's just not going to happen again because it happened in the Fall of 1998. I think it's incorrect to assume it's not going to happen again. What you have to assume is that these events don't follow the normal distribution, so talking about six standard deviations doesn't really capture how likely it is to happen again.

Now that I've painted this hopeless picture of models and said that they're all fraught with uncertainty and risk, where do we go from here? In order to redeem this situation, there are some things that we can ask ourselves about our models. First, is the model you're using right for the assets that you hold? Sometimes your model is perfectly acceptable as long as you hold only certain types of assets, and you don't really have to worry about model risk for other types of assets that you don't hold.

Another thing to realize is that some model risk is unavoidable and that's okay. We'd all love everything to be certain out to the third decimal point of precision, but that isn't possible with financial models. That doesn't necessarily mean that you throw the model out. Sometimes the model is just as I said—as good as it gets—and you have to live with the uncertainty. What you can do is quantify the potential for error that your model risk represents by tweaking some of the key assumptions in the model. If you tweak a key parameter a little bit and the answer changes by a lot, you know you have significant model error. But if you tweak your model assumption by some reasonable amount and the answer changes by only a small degree, then you can probably conclude that you just don't have that much model risk. I think the right exercise to go through is to find the key modeling parameters that affect your output your valuation, your cash-flow forecast or your total return analysis. Find the key assumptions affecting those answers and

tweak them a little bit to see how much the answer changes. If your cash flows change by just a little bit, your model risk isn't that great; if they change by a lot, you have a lot of model risk.

Here's an example of what I call a limited-use model. This is the modified Macaulay's duration formula:

$$DUR = \frac{\delta P}{\delta Y} = \frac{1}{(1 + yield)} \left(\frac{1PVCF_1 + 2PVCF_2 + 3PVCF_3 + \ldots + nPVCF_n}{\text{Total PV (Price)}} \right)$$

The formula does not accommodate a change in cash flows when interest rates change. Therefore, it should not be used for callable bonds, mortgage-backed securities, adjustable/floating rate securities, asset-backed securities, etc.

We all learned this formula in school. It says that the duration of a fixed-income asset is given by this formula, and it basically tells us that a change in price for a given change in yield can be estimated by plugging numbers into this formula. If the number is four, that means that a 1% change in yield will produce approximately a 4% change in the value of this security.

Macaulay's duration is a very limited use model because it doesn't allow for the possibility that the cash flows in the numerator might change when the yield in the denominator changes. It only determines what happens to the present value of the cash flows when the yield in the denominator changes. It doesn't allow for the possibility that the cash flows themselves are moving around. As such, you really can't use this model when you're looking at callable bonds, mortgage-backed securities, CMOs, adjustable or floating-rate securities that have interest rate caps in them, and certain asset-backed securities. This Macaulay's duration formula just won't work for those things because all of those securities have cash flows that can change as interest rates change.

Another way of saying that is, some securities have embedded options and the value of those embedded options changes due to changes in underlying interest rate. If all that you have in your portfolio are noncallable Treasuries, or noncallable corporate bonds, Macaulay's duration is a

fine interest rate risk model to use. But know when the model is appropriate for the assets that you're dealing with.

Now we will see how matters become more complicated. Does anybody know what you should be using instead of Macaulay duration? Option-adjusted duration or effective duration is the type of a duration expression that captures the change potential for changes in future cash flows due to a change in interest rates. It is important to know whether a duration that's reported is, in fact, option-adjusted (or effective using those two terms interchangeably).

Modeling path-dependent assets complicates matters further. Some fixed-income securities are what we call path dependent, and that means that their cash flows will vary not only depending upon the level of some underlying variable or underlying interest rate, but also depending on the path that interest rates follow.

For example, imagine you have a pool of 8% mortgages. In the current interest rate environment, the homeowners with those mortgages have a negligible incentive to refinance. Now imagine we're trying to forecast the cash flows for the securities for the remaining life of the instrument.

Let's say we want to find out what cash flows we are going to get in year two. If I say interest rates are at 6% in year two, you might think, in year two I'm going to get a lot of people refinancing those 8% mortgages, resulting in a lot of cash flow.

What if I now tell you that interest rates will drop to 6% tomorrow and they stay there for the next two years versus interest rates staying at 8% for the next two year and then dropping to 6% at the end of year two? At the end of year two, we have 6% interest rates under both scenarios but we reached the result in a very different fashion. If interest rates drop tomorrow, then at the end of year two, many of the homeowners with 8% mortgages will have already refinanced, at least everybody that's going to. At the end of year two, I won't have very many people left to send in their refinancing checks, versus the second scenarios where interest rates stayed where they were for two years and then dropped. In that scenario, at the end of year two, I'm going to get a flood of refinancing, so depending upon the path that rates follow, I'm going to get very different cash flows in year two.

For this kind of path-dependent problem, the only way that we know how to compute the value of the security with those uncertain cash flows is to explicitly model the different path that interest rates might take. We can compute the cash flows along each one of those paths and solve for the average present value of those possible future cash flows. That's what's known as a Monte Carlo approach to modeling a path-dependent asset. The term Monte Carlo just refers to the process of generating a random or sometimes a quasi-random sample of interest rate paths.

What you might ask yourself is, does the model you're using to value mortgage-backed securities have the ability to model path dependency using a Monte Carlo type of an approach? If you don't have a model that can incorporate this path dependency, chances are you're using a single lifetime prepayment speed to compute a single set of cash flows for mortgage either under today's interest rate environment or given some interest rate shift. Then you're discounting that single set of cash flows from that prepayment speed based on either today's interest rate environment or based on some shift that you're imposing in some scenario analysis. You're discounting those new cash flows in a static way, as I recall it, and the result is you're ignoring the possibility that there's going to be interest rate fluctuations in the future.

If current interest rates are 8%, and if you look at how mortgages with an 8% coupon are prepaying, you would be putting on blinders to the possibility that interest rates could rise or fall in the future if you're not using a Monte Carlo-based approach. That's a very severe model limitation. For those of you who like to think of things in terms of option theory lingo, the time value of the prepayment option is ignored for those of you who like to think of things in terms of option theory lingo. I would go so far as to not call this model risk. I'd call it model insufficiency. If you don't have a model that can generate a Monte Carlo type of path-dependent valuation, then the model is inadequate for the purpose of capturing mortgage-backed security characteristics.

I have a confession to make. I'm not a mathematician; I'm not a statistician; I'm actually quite bad at math, so getting up in front of a room full of actuaries is a little intimidating to me. Below is the math behind a Monte Carlo simulation:

$$PV = \sum_{k} p_k \sum_{n=1}^{N} \frac{C_n^{(k)}}{(1+r_1 + S)(1+r_{1,2}^{(k)}+S)...(1+r_{\underline{n}\text{-}1,n}^{(k)}+S)}$$

k = path; $r_{\underline{n}\text{-}1,n}$ = short rate at time n; S = option-adjusted spread

It says that to value a mortgage-backed security or path-dependent asset, you find that the present value of the future cash flows under various paths denoted with a *k*, and the cash flows denoted with a *c* at each time end are discounted at *r*, which is generated by some term structure model or some interest rate model.

We see the short-term interest rate, *r* at time *n* along path *k*. The option-adjusted spread (OAS) is used to discount your cash flows. That option-adjusted spread is the number that we layer on top of *r*, the short rate, such that the present value of these path-dependent cash flows equals the market price today. In other words, we plug in the market price, and we solve for the OAS, given all of these other inputs that come out of models.

How many modeling assumptions can you spot in the Monte Carlo Simulations? How many model risks are there in this formula? This is a pretty easy formula for actuaries. I would say that there's an assumption about your paths labeled with a *k* there. What term structure model are you using to generate those paths? There is an assumption about the risk-free rate, and the relationship between the risk-free rate and the cash flow that you're going to get. Right now mortgages have an interest rate that's roughly about 150 basis points higher than the ten-year Treasury rate. Is that a good assumption? Is that a bad assumption? Is that assumption going to hold?

Then there is the S, the option-adjusted spread. If you're going to try to value this security at some future date, can we assume that the option-adjusted spread today is going to be constant at some future date? That is an assumption that most models make because we haven't come up

with any better assumption, but note that it is an assumption. I see at least three assumptions in this formula, and there probably are more.

Another thing that's an unavoidable model risk with mortgage-backed securities is prepayment modeling. Probably the most critical aspect of mortgage-based securities modeling is forecasting how much a homeowner will prepay given a certain interest rate environment. People prepay their mortgages for different reasons as we all know. Sometimes it is because there's an economic incentive to do so, but other times, people prepay their mortgages even when it doesn't seem to make economic sense. They move, get another job, get a divorce, get married, or whatever. People prepay their mortgages unpredictably, and no two prepayment models will produce the same forecast.

Even if you look at the best and brightest on Wall Street or in our firm or other firms, everybody is going to have a different model. We use different data sets, or different variables, or different weightings for the data sets. Some of us might take the last five years' worth of prepayment experience and give them all equal weights. Other people might assign a heavier weight to the most recent three years. There are all sorts of differences that go into prepayment modeling that will cause the results to differ. You can also observe that prepayment models are based on historical data that might not reflect today's market conditions. A couple of years ago, you could look at a prepayment model that was based on the previous five years' worth of prepayment data and make the very important observation that the prior five years of historical data said nothing about the possibility of people refinancing their loans via the Internet. That is because the Internet didn't exist in the prior five years' worth of data. So if the Internet causes people to refinance more rapidly than in the past, that wouldn't be reflected in the data sets used to fit the model. The way that market conditions can change is something you should be aware of.

Given all these differences in prepayment models, there's this uncertainty associated with valuing the securities, analyzing the securities, and projecting cash flows for the securities or what have you.

Let's briefly review how a prepayment model tries to go about forecasting prepayments. We look at factors such as the mortgage's age, which is also called seasoning. If I just took out a mortgage three months ago, chances are I'm not going to go through the paperwork of refinancing in the immediate future. Chances are I'm not going to sell my house and move that sort of thing. So for very new loans, we don't expect to see a lot of prepayments.

Similarly, for very old mortgages, or "highly seasoned loans" as we call them, there is little chance of refinancing. If Aunt Polly has held on to her house for 25 years, and there's only five years left on the mortgage, there's not a whole lot of probability that she's going to refinance the loan tomorrow. There's a slight possibility, but it's not very big. There's also the refinance incentive threshold. Does it take a 50-basis-point incentive or a 75-basis-point incentive for me to refinance my mortgage? What's going to be the trigger? How quickly are people going to rush to the bank to refinance when they have a small economic incentive to do so? The time of year is also important. There are heavy prepayments in May, June, and July because people try to move when their kids are out of school, and there are very low prepayments, relatively speaking, in the winter months. Another important factor, called *burnout* refers to the phenomenon that a seasoned pool of high-coupon mortgages will not show much prepayment activity because the homeowners with those mortgages have already faced numerous opportunities to refinance their loans but have not done so, and are unlikely to change their behavior in the future, despite new refinancing opportunities. All the people in those pools who were going to refinance have already done so. The people who are left, for whatever reason, are just burned out. We don't expect to see as much prepayment out of a burned out 9% pool as we would from a pool that contains fairly new mortgages. Those are some key parameters that go into prepayment modeling.

You are probably familiar with the notion of the Dealer Median prepayment estimates. A dozen or so Wall Street dealers are polled about their model predictions for prepayments on mortgages with different coupon rates. The median prepayment estimates are published and everybody points at the dealer median as though it's some gospel truth saying, "Well, that's the speed for that kind of mortgage." However, we knew that a median is just one statistic, and it really

doesn't tell you enough to draw a particularly meaningful conclusion about the underlying models that produced the median estimate.

Table 1 shows the dealer median prepay estimates for 7% and 8% mortgages. The middle column is labeled zero. That reflects a zero-basis-point shift; in other words, today's rate environment. The median prepay estimate for 7% is 140% PSA. The high and low is 150% to 126%, so there is some variation in the estimates from the dealers. If you go up or down 100 basis points from there, you can see the high and low estimates from these dealers differ by more than 25%. All of these dealers are from very good Wall Street firms. They significantly disagree with respect to how different mortgages are going to prepay. That's just a model risk that we all have to live with.

TABLE 1
Prepay Estimates: Beyond "the Median"

New 30-Year Collateral: Dealer Prepay Estimates						
	7% WAC			8% WAC		
bp shift	-100	0	+100	-100	0	+100
Median	205	140	121	479	196	141
High	246	150	134	612	207	146
Low	194	126	104	395	166	125
% Difference high/low	27%	19%	29%	55%	25%	17%

Given the fact that there is this uncertainty about prepayment modeling, I think we can clearly see that the true duration or price sensitivity of a mortgage-backed security is unknowable. We can't know the true duration of a mortgage; there are just too many moving parts in our models. The one thing you might want to do to deal with this model risk or uncertainty is to compute what we would call duration bands. A duration band would say, for example, that the duration of moderately seasoned collateral with a 7.5% coupon is 3.7 to 4.1, somewhere in that range, if prepayment speeds are shifted up and down 10%. In other words, take your prepayment model, compute a duration, shift the prepayment speeds faster by 10% and slower by 10% and recompute the duration. You end up with a band, and you can feel fairly assured that the duration of this type of collateral is within this range. I feel more comfortable saying that than I would saying it's definitely 3.9715. You really can't know what the precise duration of a mortgage-backed security is.

You can even take a finer approach and say the duration of 8% new collateral is between 3.2 and 3.5, assuming a refinancing threshold of somewhere between 50 and 75 basis points. In other words, I don't really know what refinancing incentive is going to cause people to rush out and refinance, but I assume it will be between 50 and 75 basis points. Given that assumption, I can compute a band of durations for a particular type of mortgage collateral.

Another approach you can take is equally valid and equally interesting. You can compute a price uncertainty measure and ask the question: how sensitive is your valuation to a misestimate in prepayment forecasting or a misestimate of the amount and timing of cash flows? We compute that in a similar fashion. We adjust our prepayment speeds, which we call single monthly mortality rates, along each interest rate path as determined by the Monte Carlo simulation. We shift our prepay speeds up and 10%, and we compute two new prices. The percentage change in price given prepayment speeds that are increased and decreased by 10% would give us a price uncertainty measurement.

Our approach looks at duration uncertainty, i.e., how much does my duration change, given a 10% misestimate in prepayments? This approach shows how much price changes when there is a 10% misestimate in prepayments. It's just two ways of looking at prepayment model risk; both are equally valid.

FROM THE FLOOR: It seems that some lenders are going to a higher loan-to-value ratio than the usual 80% before requiring mortgage insurance. I wonder if this is another type of incentive for people to want to refinance. Even if interest rates weren't lower, they could get rid of the mortgage insurance by going to another lender who allowed a higher loan to value. I was wondering if that type of loan might become more popular among lenders because of the competition.

MS. GESKE: Apparently some lenders are offering loans with higher loan-to-value ratios, like 85% rather than 80%, before they're requiring private mortgage insurance, and private mortgage insurance is expensive. The question is, if you were allowed to have a higher loan-to-value ratio without having private mortgage insurance, would that potentially cause you to refinance more

quickly? I think that would change refinancing patterns. I don't know how popular or unpopular that's going to be with lenders. There's more credit risk that you take on with a higher loan-to-value ratio. I do think lenders are getting more aggressive because it's a competitive business. That's one of those changes in the market conditions that I was kind of alluding to earlier where an historical data set might not reflect current prepayment patterns; there's just a fundamental shift in something about the collateral characteristics you're trying to model, so I think the answer is yes.

FROM THE FLOOR: What does 140 mean on the chart you showed?

MS. GESKE: That 140 refers to something called PSA. PSA is a way of expressing a prepayment speed, and it was derived by the Bond Market Association, which used to be called the Public Securities Association. PSA stands for Public Securities Association. It's now called the Bond Market Association.

Many years ago, the PSA came up with this way of expressing prepayment speeds, such that everyone could know what you meant if you said 100% PSA. In a simple sense, it means that 6% of the loans that remain in a pool are going to prepay that year. I did simplify it a little bit because it's a little trickier if the loans are new. Assuming the loans are fairly well seasoned, 100% PSA means that 6% of the loans remaining in the pool are expected to prepay that year. Therefore, 200% PSA means that 12% of the loans in the pool are expected to prepay that year; 300% PSA means 18% of the loans in that pool are expected to prepay that year. Everybody who sees 140 PSA knows that you would take 6% and multiply it by 1.4 to come up with a cash-flow forecast. It doesn't really capture the richness of what a good prepayment model does; it's just a summary characteristic that everybody understands in the mortgage-backed securities market.

The last issue about model risk that I am going to cover has to do with volatility, which I think, in addition to prepayment model forecasting, is one of the key variables that you should be aware of when you're evaluating any asset model. Volatility estimates, as I say, are a critical input in modeling securities with embedded options. Why is that? Those of us who took the class in options will remember that higher volatility makes all options more valuable. If I were to give

you the option to buy avocados from me anytime over the next year at the price of $1.00 per avocado, how much is that option worth? We can't say, because I haven't given you enough information. First, you need to know how volatile avocado prices are. If avocados have ranged in price from $.25 to $3.00, the option to buy them from me at $1.00 has a lot of value. However, if you learn that avocado prices have been 85 cents for the past five years, then the option to buy them from me at $1.00 doesn't really sound too attractive. What you're willing to pay me for that option depends upon the volatility of the price of the underlying thing that the option is on. So options get more valuable as volatility increases, and volatility is a very important input to any asset model or any liability model.

There are two basic approaches to figuring out what volatility is. In the case of the avocados, we used historical volatility. We said that over the course of a year, avocado prices had ranged from $.25 to $3.00. In other words, we looked back over some historical period of time and actually observed the volatility of the underlying. That's called an historical volatility estimate.

Another approach is to look at the price of the option itself (you can go to the Chicago Board of Exchange (CBOE) and look at the price of stock options). Embedded in that option's price is a volatility assumption, because you have used a model to calculate the option's price, and one of the inputs to the model is the volatility estimate. So, given an option's price, you solve for the implied volatility estimate. That's the implied volatility that the market is using to come up with a price for the option today. Oftentimes, implied and historical volatilities will not be the same. It also happens that in many financial markets, implied volatilities actually are higher than what the ex post historical volatility ends up being, and there are endless academic arguments as to why that is. You could say, "Since implied volatility is good and historical volatility is good, I'm going to take half of each and add them together." That's probably not a bad approach. Just know that there are debates and arguments about which approach is best in coming up with your volatility estimate.

If your volatility rates are too low, your model won't adequately sample interest rate paths in the case of valuing fixed-income securities, where a low-interest-rate path or a high-interest-rate path could cause your cash flow to change significantly. If your volatility parameters are low, interest

rates won't fluctuate much in your model and you won't sample any paths that go up or down dramatically. If these dramatic rate moves are the ones that are going to cause you to have a big change in your cash flows, then having a low volatility estimate can understate the value of the embedded option.

If your volatility estimates are too high, then you overestimate the risk of extreme interest rate moves and you overvalue the embedded options.

What can you do to decide how sensitive your model's outputs are to your volatility estimates? You can change the volatility estimates to see how the model results differ. In our system, for example, we compute a measure called vega, which is the sensitivity of price due to a change in volatility. We shift our model's volatilities up and down say from 11% percent down to 10% and then up to 12%, and we compute two new prices for a security. We haven't changed anything else. We haven't changed where interest rates are today. We've just changed how volatile they're expected to be in the future. We compute two new prices, and we measure the percentage change in price given these two new volatility estimates. The average change in price is the vega. Vega is positive for most fixed-income securities except putable bonds. For most fixed-income securities, if there's an embedded option, the investor has shorted the option. If you're short the option and volatility goes up, you'll lose value because you've shorted something that has an increasing value. With putable bonds, you own the option so if volatility goes up, the value of the security actually goes up. The result of this means that for fixed-income portfolios, it is difficult to diversify away your volatility risk (without using interest rates derivatives such as caps and floors). There are some ways, but you typically have to go into some derivatives to do that.

In closing, I want to mention an article I read in the *Journal of Portfolio Management* by Emanual Derman that was wonderfully refreshing. Derman is a very well-known academic, a physicist who went to Wall Street and works with traders. He wrote this article called, "Valuing Models and Modeling Value." He points out that, unlike models in physics, which explain the past or predict the future with accuracy, models in finance give you a set of plausible variables to use in describing the world and a set of relationships between them that people believe are true.

He also says that illiquid or over-the-counter markets (such as the bond market, where models are most useful) are the hardest to capture accurately.

Occasionally, model use and pricing become almost circular. Some traders use a model to mark their mortgage prices. When you compare historical prices to their model, guess what? They look the same—imagine that. You're simply extracting their assumptions. It's good to remember that you really can't get away from model risk—asset modeling is inexact and it affects everything you do. However, you can quantify the potential for model error by tweaking some of the key parameters to see how much the answer changes. I would urge you all to question your key modeling assumptions, but don't worry about them if the assets that you hold are not affected by a change in those assumptions.

MR. JACKSON: I'm a senior vice president at Scudder Kemper Investments. I work for the insurance asset management arm. We manage assets for over 100 different companies. I've acted as the investment actuary for the firm for almost eight years.

I would like to give specific examples. My clients want modeling that's really effective and that really helps them make decisions. One of the concerns that many of my early clients had was that the models didn't really help them move toward effective management action. I put in here some specific examples that I think have shown me that, as Teri says, none of these models are exact or are "correct," but they do provide the kind of information that lets us make effective management decisions. They do help us focus on risk.

Model risk. There is a potential for error due to modeling limitations and/or assumptions that are imprecise, outdated, or do not hold under extreme market conditions. This brought to mind a specific instance.

In a graph of the modeling process, we'd see that it has reasonable accuracy for level and rising interest rate scenarios, but it really failed in falling interest rate environments. I guess there were two companies early on that tried to keep costs down. They did not use the more robust CMO

portfolio modeling capabilities that were available to them. What they ended up doing to save cost was to use the sinking fund proxy portfolio to represent the CMO portfolio.

We have a New York 7 scenario and we have three different robust modeling systems. One is Solomon Brothers yield book. There is Intex, which does the most extensive job of modeling the deals that are out there. Intex takes the prospectuses. It has excellent coverage and does not have portfolio analytics. It lets other systems, like the Chalke system, take the information and run it through its analytics. There is also the CMS BondEdge from Teri's company. I'll give credit to it as being the most user-friendly systems for insurance companies. They have interfaces that allow you to have access to their cash flows. They interface very well with the AOM systems that are out there, and they've made a huge effort in that direction.

The sinking-fund modeling, on the level and rising interest rate environment, tracks very well with the more robust modeling systems. The sinking-fund modeling stays well above the run-off of the CMO portfolio. That's because the prepayment stage, as Teri indicated, picks up very quickly. You have the portfolio running away from you. It would have to reinvest at much lower rates, so it's a very significant impact. This is a very inadequate way to model the CMO portfolio, but, initially, some of our clients did go this route.

As I said, acceleration is reflected in more robust modeling options of the yield book interest of CMS. This process fails dramatically for falling interest rate scenarios. What I'm more interested in are what are the consequences of this modeling process? What does it mean for an inadequate model? In this particular case, I think that the results, compared to some of the ones we're going to see later, are relatively modest. They resulted in the two situations that I dealt with.

One of these companies that used this process really had no impact at all. It slipped by the regulators, and there was no penalty at all. One of the companies was actually challenged by the regulator. The regulator looked at the asset adequacy filing, asked for information on the modeling process that was used for the CMO portfolio, and wasn't satisfied with the results. He

challenged the asset adequacy filing. The valuation actuary had to come back with an explanation.

Actually, in falling interest rate environments, the liability structures that the company was dealing with were doing very well. This really would not have an adverse impact upon the results of the cash-flow testing. The company got by it that year. The result was that it was required to purchase the more robust model the next year. That's an appropriate and rather modest penalty for this particular process.

Model risk is not equivalent to market risk. Teri pointed out that market risk is really risk of loss due to changes in interest rates. I've been with a firm for many years. In the early years with this investment firm, the earnings volatility that was unknown or was understated was much more prominently highlighted by interest rate scenario analysis. What I've also found in the last few years is that this preliminary modeling to assess the interest rate volatility has sometimes exposed more significant portfolio-related issues.

A few years back, we looked at Company A's New York 7 scenario. This particular company had a significant mortgage-backed presence. There was probably a much heavier concentration than the company was really looking for. What we originally started to do was just confirm that. In a chart reflecting the New York 7, we'd see underperforming market value results—the fallen return and the pop-down environment. The particular product did show unsatisfactory results of the product, and portfolio combination showed unsatisfactory results where you had a falling interest rate environment. There is volatility in this particular block of business because of the mortgage-backed security. We went a little bit further with this modeling. So we did conclude that the heavy mortgage concentrations did introduce falling interest rate risk to the profitability. Since we had this model in place, we wanted to find additional uses we could make of it. We compared it with a portfolio backing similar liability structures. There's a duration mismatch involved here. Typically, a duration mismatch is much more common, especially with annuity structures when we have a liability duration of three and an asset duration of four or five. This is a mismatch; assets are positive. Some risks are taken to get the additional return.

In this particular situation, for reasons I really can't share, the asset portfolio was not directly tied to the liability portfolio. What we really had was a mismatch in the other direction. We had liabilities. Duration was around six to eight and the asset duration was more in the three-to-four range. After we identified that the mortgage-backed security concentration did introduce volatility and down interest rate scenarios, we asked if there were other impacts on the way that this particular company has invested behind this liability. Was there a failure to really invest to reflect the liability structure? What we did is we had another company with a similar liability structure. We took their portfolio, which we had managed for several years. We had a set of guidelines that tried to match duration pretty closely. We know what our yield targets were, so we just kind of overlaid that portfolio on this particular liability structure.

The results were rather dramatic. With Company B overlaying the alternative portfolio, we really didn't change the interest crediting on the liability structure for Company A. We took a portfolio that largely had a duration more closely in the range of six to eight. The yield give-up that was put on during a normal yield curve environment really proved devastating to future profitability.

Let's discuss Company B's alternative portfolio. When you take the valuation differential and look at the market value of surplus over the next 20 years, there was between a $54 million and an $87 million difference. We're grossing this up to a billion dollar portfolio. There was that level of market value of surplus differential because an inappropriate portfolio was matched to this liability structure. We made sure that, in the analysis, the additional spread was maintained throughout the projection period. This showed us that there was a problem with the mortgage-backed concentration introducing volatility, and there was a much more significant problem in not matching the assets appropriately to the liabilities. Ideally, this company would have liked to have swapped this portfolio out for this other Company B portfolio and dramatically improved the value of the company by doing so. That obviously wasn't an option. What was considered was portfolio restructuring. The reality of the situation is that because this portfolio was put out over time under different conditions, a full remedy on a par with the other company portfolio was not possible. We ended up restructuring and getting to a more appropriate duration and taking some capital losses in this particular situation. We put a portfolio in place that is much more

appropriate. It did result in a much better market value of surplus, but it didn't quite get to the point where that other company was.

This was a case where we really got some additional benefit. We did the initial modeling to assess a risk and then realized, afterward, that it was an even more important revelation that came through because of the modeling process.

Model risk is not credit risk. Credit risk is a risk of loss due to default/downgrade. There was a company we were doing some work with where analysis was started as a volatility evaluation for a CMO/asset-backed securities block of business. Structures were purchased for yield and current credit quality. We took a look at some of the asset adequacy work where, in the same context, there was an asset adequacy. It showed some modeling adequacies on the assumption of a single cash-flow stream.

In this portfolio, for cash-flow-testing purposes, there were limited tools available to illustrate how this portfolio would run up over a ten-year period. The assumption was that one set of cash flows was appropriate. So this top-level assumption was used across-the-board for the cash-flow testing. We used CMS, and we regularly use CMS tools. We compared the rising, up and down, and pop-up situations. Those are pretty close to the level cash flows, but with the falling down/up, pop-down situations, especially in year five and ten, we get some drop-off. This really pointed out to us that there were somewhat unsatisfactory results. Let me go to my conclusions.

The modeling issue started to surface a deeper concern. I think it grew in part out of this work. The single cash-flow stream was somewhat inadequate, but it was not devastating for this particular portfolio. Then, a different story emerged when we took a look at some of the credit issues of the CMO asset-backed portfolio. We had our research team assess this particular portfolio, and comparable to most life insurance companies that are buying for yield, this company, a few years ago, was buying for yield and then holding. They found that buying for yield and then holding has its risks. They weren't really looking that closely at the structures after purchase.

The other issue that was going on here was that the failure to diversify adequately by issuer proved to be very risky. In this particular situation, 33% percent of the portfolio ended up being concentrated in a single issuer rather than the standard 2% maximum. We typically, in our investment guidelines, will make sure that you don't put more than 2% in any particular one issue.

In this particular case, because of some consolidations that were going on in the industry of CMOs and asset-backed securities, there ended up being a 33% percent position in a portfolio. It's an approximate $150 million portfolio. We looked at the portfolio as it was in a buy-and-hold situation. It became clear to us that there was pretty much a nonrecoverable principal hit that was in effect. Approximately 10% of the $50 million that was in this single issuer was under duress and 10% of the $50 million portfolio under duress that had a nonrecoverable principal loss, was really a $5 million loss of principal that's being examined. What started out as an initial look at the volatility of the modeling process, as part of a process of working through this, led to additional analysis that really demonstrated that this portfolio was having serious difficulty.

Teri pointed out that the asset models want to capture path dependency. Prepayment modeling is very critical.

Teri mentioned the risk manager and how price sensitivity measures exposure limits such as duration and convexity. We had a real situation where a company was not paying close attention to its duration match or mismatch. The particular annuity writer had an SPDA on the books with a 150-basis-points teaser rate in year one. They had a market interest crediting rate in place and a resulting liability duration of one on the annuity block of business. Their asset portfolio was at five, so what you really had was a mismatch of five to one. As we've seen before, the risk in rising interest rate environments was significant to this block of business.

We presented an alternative with two changes. They first must go from a market interest crediting strategy on the annuities to a portfolio interest crediting strategy. If you have done this work, you've seen that that can change your liability durations on the order of taking the annuity

portfolio from one to on the order of three. That would affect the mismatch somewhat. We also suggested that the asset duration be reduced from five to four. With an asset duration of four and a liability duration of three, the mismatch would actually have been one, which is more in line with appropriate use of duration. There is a much more typical duration mismatch.

The company was sold. The investment banker that did the transaction, came in, did the work, looked at it and saw that the duration mismatch was on the order of five to one. As part of the sale agreement, the company imposed a restructuring program on the whole transaction that cost in the neighborhood of $2 million. This affected the value of the sale because of the execution cost. It also subjected the buyer and seller to current market values because the portfolio was put in place at then current market values. For the most part, the result was neutral. We were out of this transaction at this point, so we really didn't get to see the values. The transaction went through so I have to assume that the seller either came out even or was hurt by the translation to market values. If the deal had not been good enough, the buyer would not have gone through. This is a particular instance where failure to reasonably match duration of your assets and liabilities did have a real impact at the time of sale.

I'd like to go through some conclusions. Teri brought up the point that duration should not be used for callable bonds, mortgage-backed securities, adjustable/flash floating rate securities, ABSs, and so on. What I found when I started seven or eight years ago was that portfolio managers were very comfortable with duration. They're asking for duration. When you're talking with investment people, you're going to start with duration. It's unfortunate that it stays at duration. I guess my conclusion here would be that, too often, duration is the primary portfolio management metric for too many life annuity companies. I believe that's changing and that the scenario testing is being recognized as a much more appropriate way to evaluate risk. Investment people have to start with duration. You really have to start talking duration with investment people. You can hope that the next step is to bring them to scenario testing.

It's especially dramatic if the combination of annuity block has a heavy mortgage-backed security exposure. You get a lot of volatility. A.M. Best reacts very significantly to anything over a 30%–35% mortgage-backed security exposure if there's a heavy annuity concentration.

Without Monte Carlo, the possibility of future interest rate volatility is ignored. If Monte Carlo isn't used, then at least the stress testing of the New York 7 is a must. Some companies continue to do their original pricing without looking at the New York 7.

The last point is no prepayment model is correct. I guess it comes back to the statement that any of our modeling assumptions can be challenged. You might have many different choices of prepayment models, but the alternative of a sinking fund with only fixed cash flows can give you very inaccurate results.

With that, I think we'll take questions.

MS. GESKE: I have a question somebody handed me. The question is, Teri, it seems most of your comments apply to single-asset analysis. Suppose I wanted to compute the price duration in other metrics of a portfolio of similar assets. Most actuaries do not concern themselves with the trading of assets, but need to evaluate the duration and convexity of a portfolio of assets. Do my modeling risks compound with a portfolio or do they offset each other?

That's a great question. Although I was using single securities to illustrate most of the model risks I talked about, I must say that you can and must compute them in a portfolio context. That's the context that you're ultimately working toward, and using single securities is really just a good way to illustrate the concept. I wish I had an easy answer, though. Sometimes there are offsetting or diversifying effects, and sometimes there are compounding effects. Take mortgage-backed securities. Say you have a portfolio in which some of the mortgages have the high coupons and some of them have low coupons. If your prepayment model is biased toward prepayments being too fast or too slow, and if you have some of those premium mortgages and some of those discount mortgages, then they'll potentially offset each other as far as a model bias, as long as the model bias is consistently biased. But I have seen some models where prepayment speeds on premium or high-coupon collateral are too fast and prepayments on low coupon collateral are too slow. You don't have a consistent bias; you have an inconsistent bias, so there really isn't an easy answer to that question. I think Rick's point about stress testing is one that I should have mentioned. It's really great to go in and assess your model risk by doing

the type of model parameter tweaking that I talked about. However, that is no substitute for just going in and stress-testing your results. Put in a standard deviation move of five and see what happens. That's really important.

MR. JACKSON: I guess I would add that stress testing on the asset side is kind of relatively newer to actuaries. I think we've all looked to stress test the morbidity and stress test the mortality because those are very clearly volatile assumptions that you can only stress test, unless you run it through a stochastic process, as some folks are doing these days. Teri's firm does stress testing on the asset side. You should make the time to do this.

I'd like to respond to the question about whether individual security issues compound. There is something we try to do when we deal with companies, and I hope all of you folks are doing the same thing as well. Before your portfolio managers invest or change the way they invest or come up with a new product, they go to the actuaries and look for the liability characteristics to get some sense of how the liability characteristics are going to perform so that they appropriately match the assets that are built into the guidelines. You want to make sure that you diversify appropriately. If you have a volatile annuity block of business, you should not put too much in the way of mortgage-backed securities to back it. The reason is, if you start out with a matched block of business or a closely matched block of business, when interest rates rise, the duration of the assets will go in one direction and the duration of the liability will go in the other direction. When you have the opposite occur in a falling interest rate environment, your mismatch is exaggerated in both situations, so you really have to know what your liability structures are. Our portfolio managers always come to us in advance and make sure that, as we are setting the guidelines and they are setting the guidelines, we know how we want the assets and liabilities to interface.

We're not supposed to plug our own systems, but I don't think Teri will mind if I plug CMS. There are robust systems that are laid out there that allow you to test. I have a complaint about Solomon Brothers yield book. It's a very good system, but it seems, from our point of view, to appease the portfolio managers who are looking at individual securities. CMS is very friendly towards portfolios and providing portfolios that allow you to pull all this risk together and come

up with cash-flow projections. Then, you can turn around and interface very well with the asset/liability management systems that we actuaries have to use.

MS. GESKE: Thank you for the plug.

MR. DOUGLAS C. DOLL: I was curious about the $2 million restructuring costs that you showed on one of your slides. I think some actuaries tend to either overlook them or regard restructuring costs as immaterial and ignore them. Could you comment about the source of restructuring costs and what percentage they were of the assets that were restructured?

MR. JACKSON: I probably can't except to say that it's probably a typical cost given the magnitude of the securities that were moved. Before this presentation, I called the portfolio manager who worked on this with me about four or five years ago. He had run the portfolio, and it was a rather significant transaction. It was about a $3–3.5 billion portfolio. Given the size of the portfolio, I really haven't gotten involved with too many specifics on the transaction costs, so I'm kind of taking the lead from him on that. I'm ducking your question and saying I really don't have the answer, except that was the number that he remembered very clearly as being the transaction cost on that size of a portfolio.

MS. GESKE: Based on discussions with traders and portfolio managers, if you have a very large portfolio or a large chunk of securities that you're trying to sell, the word gets out. People know and they will take advantage of it, so if it becomes known that you have to sell off a large chunk of assets, chances are you're not going to get the prices that you'd like to get. The $2 million figure is probably not at all unusual. There are vultures out there, and if they smell blood, they are going to go for it.

MR. JACKSON: Now that Teri put it in that context, I'll answer in a different way. One of my clients was very cautious in the way he handled the companies' investment portfolio. It's actually a property/casualty company that was not realizing the income that it had seen in the past. One of the things that the property/casualty companies do, because of the laws, is they invest in municipal securities. They have to be able to achieve the tax savings, and they have to

be making a profit in that particular year. They were not going to be making a profit. In the last several months, they wanted to basically turn over a large block and liquidate their municipal portfolio. This was the first time I had actually gotten involved in something like that. They wanted to liquidate within a matter of a day or two. With the size portfolio they were looking at, they had to go to five or six brokers for over 100–150 securities to get prices. The minute that word gets on the street, the companies become vultures. They're going to not give you the capital gains you think you have in those securities. The best thing to do, and what we recommended, was to execute the liquidation of the portfolio over a one-week period. It could be stretched out. You hide the fact that this was a rather quick sale that was being sought.

MR. FRANCIS C. BERNARDI: The yield curve has been weird lately. Monetary policy drives the short end and fiscal drives the long end. An item of conversation at our company in doing ALM work is, what should the yield curve shape be in the future, and what should the level be in setting parameters? I've been reading about and hearing about the swap curve. Do you find your modeling is moving to the swap curve? Is that the wave of the future, is it just a hot topic, or is it too soon to tell?

MS. GESKE: It certainly is a hot topic, and I think it's too soon to tell. I think a lot of our clients are looking at using a live work curve or a swap curve in addition to or instead of the Treasury curves. The dust hasn't settled yet. We don't really know what's going to happen if the Treasury debt is going to be retired completely or if we run another budget deficit and things change. The live work curve and the swap curve has some beneficial aspects. They tend to track changes in corporate bond prices more closely than movements in the Treasury curve these days. It does not have a risk-free benchmark, so there are some limitations with it. So our clients are asking for the flexibility to use more than one yield curve or to choose from among different yield curves until the dust settles. What will happen with the shape of the yield curve, which I think looks something like the Himalayas right now? It's very strange; I've not seen it in the eight years I've been doing those.

FROM THE FLOOR: Are you doing a lot of model swap curves now?

MS. GESKE: We're giving our clients the flexibility to choose, but we're not suggesting which ones are the right ones. We have actually surveyed people on this, the most common response tends to be "We don't know yet." That's my feeling.

FROM THE FLOOR: Do you eliminate modeling issues or do you just change the issues?

MS. GESKE: I don't think you eliminate them at all.

MR. JACKSON: I would echo what Teri is saying here. The dust is still settling. Everything is being priced currently off Treasuries. We get a lot of talk about the agency curves. There would be an agency curve replacing Treasuries, and they're under the challenges that the Treasuries will no longer be appropriate. There is one right answer to find your spreads. Every week we get a weekly spread report, and it's still off Treasuries by every asset class we're looking at. I don't see the replacement in place yet. There's a lot of talk about it, but the way we manage it each week is to look at what the spreads are off of Treasuries.