Beyond P&C:
Creating a Multi-Disciplinary Model

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Abstract

Since 1996, the Casualty Actuarial Society has issued a call for papers on one aspect or another of Dynamic Financial Analysis. In past years the calls have focused on the modeling of property/casualty companies. This year's call is the first to expand the focus of the call to DFA models that capture operations outside of the traditional property/casualty sphere. The process of developing and using models that incorporate more that P&C operations is, on one hand easier than developing a stand-alone P&C model, and on the other hand, more difficult. It is easier because it presumes the P&C model (and presumably the life or banking model to which the P&C model will be joined) has already been developed. As such, we can skip over the complex work of developing the stand-alone model or models and turn to the aspects that make the multi-operation model more complex. The greater complexities arise from the greater scope of the resulting model – there are more pieces to be thought about, more risk factors to be considered, more interrelationships to be quantified and programmed, and the end result is that much more complex with which to work.

This paper describes the process of creating a multi-operation model from three stand-alone models using the MoSes software package. The paper focuses on the process of bringing the three different pieces together into one combined model and discusses the nature of the risk factors and linkages between the pieces.

I. Introduction

The 2002 Casualty Actuarial Society call for papers on Dynamic Financial Analysis is focused on modeling financial institutions with more than just a property-casualty exposure. This paper describes a small subset of the operations of a banking institution with life and property-casualty interests in addition to the core banking operations. The company that provided the inspiration for this paper is a financial institution with a much larger focus than its property-casualty operations. In fact, one could easily say that the P&C operations are very minor in relation to the company's main banking operations. That does not mean that the company cannot benefit from an integrated modeling of

their banking and insurance exposures, especially since the banking and insurance operations are subject to many of the same underlying drivers of profit or loss.

The process of creating and implementing an integrated banking / insurance model that captures all of the company's operations is still in its infancy. This paper describes the start of the process. As such, the emphasis of this paper is on the process of developing a model that integrates the various components rather than the results derived from the model. The paper describes the structure and the cross-model linkages of the consolidated model. It does not discuss modeled results or management conclusions drawn from the modeling, as these parts of the process are still going on at the time of writing. Even without these aspects, we feel there is value to be gained from merely developing the model and thinking about the nature of the interdependencies between the business units.

The modeling environment being used is one that allows models to be created as stand-alone constructs, and then linked together via the creation of a "parent" model. This capability allows the development of a simplified model at first that can be subsequently expanded to incorporate more aspects of the corporate entity.

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II. Model Overview

The subset of the banking entity being modeled consists of the following operations:

1. Collection of money from individuals through the sale of deferred annuity products.
2. Investment of that money through the financing of residential mortgages
3. Sharing in the private mortgage insurance (PMI) risk associated with some of the residential mortgages through a reinsurance arrangement with the private mortgage providers.

The model also has an aggregation component that pulls the results from the three operations into one holding company's financial statements. Lastly, there is a common economic scenario that applies to all modeled aspects of the company.

A. Deferred annuity product

In this model, the bank sells deferred annuities to the general public. The deferred annuity product being sold is a fairly standard life insurance product. In exchange for money paid to the bank (the deferred annuity premium), the bank credits the policyholder with a rate of interest that is typically greater than what would be available for an investment of a similar amount of money in a certificate of deposit or a savings account. The crediting rate is tied to a rolling average of U.S Treasury yields, with a contractually specified floor. This creates a linkage between the growth in value of the annuities and the economic environment in which the investment has been made. This also exposes the bank to two types of asset risk. The first of these is the potential for the bank to have invested the policyholder premiums in assets that return less than the

promised crediting rate. Ordinarily, there is sufficient spread between the crediting rate and the yield on other assets in which the bank can invest policyholder premiums, but that might not always be the case. The second is the risk that policyholders will cancel their policies. In the event of policy cancellation, the bank must return the premiums to the policyholder, less any surrender charges. If the bank has invested the premiums in assets whose value has declined, the bank may not be able to sell the associated assets for as much as they owe to the policyholder. While the bank does have some protection against this risk by the surrender charge levied against early cancellation, there is always the potential that the surrender charge is not sufficiently large to offset the difference between amounts owed to policyholders and the value of the assets that must be sold to pay back the policyholders. In exchange for taking on these two forms of asset risk, the bank earns profits from any positive spreads between its investment of policyholder premiums and the crediting rate promised to policyholders.

B. Investment in residential mortgages

In this model, the bank takes the money it has collected from selling deferred annuities and invests it in residential mortgages. This is a vast oversimplification of what a bank would really do with its investable assets, but, for the purposes of this paper, let us assume this is what the bank does. In the model, the bank lends money to people looking to purchase residential properties. Some of the mortgages are provided to people who are able to put down twenty percent of the purchase price with their own funds. These mortgages do not require private mortgage insurance. Another portion of the mortgage portfolio goes to people who do not have sufficient funds to provide a twenty percent down payment. These mortgages require the mortgagor to purchase private mortgage insurance from a PMI provider. We will come back to PMI in a moment. For now we will focus on the mortgage process itself. In exchange for the bank loaning money to a mortgagor, the bank is promised a stream of monthly payments from the mortgagor that include some amount of interest payments. The interest rate is tied to the U.S. Treasury yield curve at the time of the mortgage origination.

What are the economics of PMI for a bank?

The bank requires mortgagors who make less than a twenty percent down payment to purchase PMI because of bank risk-based capital requirements. If a loan is made in which the loan amount is less than eighty percent of the underlying property value, the bank must set aside four percent of the loan amount to satisfy risk-based capital requirements. If the loan amount is greater than eighty percent of the underlying property value, the risk charges doubles to eight percent. However, if the mortgagor purchases private mortgage insurance, the bank's risk charge once again drops to four percent.

To simplify descriptions a bit, we will call a loan in which the loan amount is greater than eighty percent of the underlying property value a "higher-risk loan" and a loan in which the loan amount is less than eighty percent a "standard loan". Note that these are not

descriptions with any meaning in the banking world – they are just being used in this paper.

If a bank is approached to make a higher-risk loan, the interest rate charged for that loan will be higher than what would be charged for an equal loan amount on a standard loan. The economic question facing the bank, then, is: "Is the potential extra profit I can make on a higher-risk loan worth the additional capital I will be forced to hold in support of that loan?" If the answer is No, then the bank's alternative is to require the mortgagor to purchase PMI. This allows the bank to treat the loan like a standard loan, since much of the risk associated with the higher-risk loan has been transferred to the PMI provider.

What are the risks the bank faces from making residential mortgage loans?
The bank is exposed to two types of risk from their residential mortgage investments. The first is a prepayment risk. If interest rates decline, mortgagors will be more likely to refinance their mortgages. This results in the return of the bank's loan to the bank much earlier than the bank had anticipated. The bank must now reinvest the repaid mortgage amount, most likely into investments yielding less than they were receiving on the now repaid mortgage. This can result in a narrowing of the spread between the crediting rate the bank has promised to its deferred annuity investors and what the bank can earn on the invested funds. This in turn leads to decreased profits or possibly even losses for the bank. The second risk is that of mortgage default. If the value of the property securing the mortgage falls below the level of the mortgage and the property owner defaults on the mortgage, the bank is left with an asset whose market value is less than the face value of the mortgage loan. This is exactly what happened in Texas during the savings and loan crisis of the early 1980's and in New England in the late 1980's.

C. Private mortgage insurance

It is to protect banks against the situation in which property values decline below the face amount of a mortgage that private mortgage insurance exists. The greater the "loan-to-value" ratio of the mortgage amount to the property value, the riskier the mortgage is. The standard rule is that if a property purchaser can provide twenty percent of the purchase price, no private mortgage insurance is required. If the property purchaser cannot put down twenty percent, he or she must purchase private mortgage insurance in addition to making the loan repayments. The private mortgage insurance protects the bank in the case of a mortgage default. If a property owner defaults on his or her mortgage and private mortgage insurance has been purchased, the PMI company will do one of two things: either pay the bank a contractually specified amount or pay the bank the face value of the mortgage. Either way, the bank recovers some or all of their potential loss from the mortgage defaults because of the PMI.

Example 1

An example of the way private mortgage insurance might work is as follows:

- Suppose a home purchaser buys a home for $100,000. To do so, the homebuyer takes out a $95,000 mortgage with an interest rate of 8%. The homebuyer is the mortgagor and the bank is the mortgagee.
- The bank requires the homebuyer purchase private mortgage insurance to protect the bank in the case of default. The PMI terms include the following items:
  - Coverage level – the maximum amount that will be paid by the private mortgage insurer to the bank in the event of a default. On this loan, the coverage level is equal to 25% of the original mortgage amount.
  - Premium rate – the annual amount, as a percentage of the loan's face value, which the mortgagor must pay to the PMI provider. On this loan, the premium rate is 0.67% of the original mortgage amount.
- The homeowner makes payments for two years before defaulting on the loan. The remaining principal equals $93,200. In the intervening two years, the housing market has deteriorated, leaving the house with a market value of $80,000.
- With no PMI, the bank would stand to lose $13,200, the difference between the outstanding principal and the market value at the time of the mortgagor's default.
- With PMI, the PMI provider has two alternatives – either pay the bank an amount equal to the coverage level or pay the bank the outstanding principal balance and take over the rights to the mortgage. In this case, the PMI provider would do the latter, because it is cheaper to pay the bank $93,200 in exchange for an asset worth $80,000 (i.e. a loss of $13,200) than to pay the bank 25% of 95,000, or $23,750.
- Because the bank receives an amount equal to the outstanding principal from the PMI provider, the bank suffers no loss. The PMI provider absorbs the entire loss.

Example 2

Suppose, instead, the market value declined more precipitously to $65,000. In this case:

- The PMI provider would pay the bank the contractually stipulated coverage level, or $23,750.
- The bank would retain the ownership of the defaulted property. Assuming the bank sold the property immediately, the bank would realize a net loss of $93,200 – 65,000 - 23,750, or $4,450.

To complicate matters, the bank has a reinsurance contract with the PMI provider. This allows the bank to share in the profits (or losses) arising from the sale of PMI. In this way the bank reacquires some of the mortgage default risk that was passed on to the PMI provider.

The reinsurance can either take the form of a quota share or an excess of loss arrangement. The underlying PMI coverage is organized according to "book years", or the year in which the mortgage getting the PMI coverage was originally written. One reinsurance contract covers claims arising from one book year.

For example, suppose the company loaned $1 billion for residential mortgages in calendar year 2000 and $1.1 billion in 2001. This is equivalent to two book years. There would be two separate reinsurance contracts in force, one for the 2000 book year and a second one for the 2001 book year. Any reinsurance payments made by the first reinsurance contract (the one for the 2000 book year) would be contingent upon claims arising from the $1 billion book of mortgage loans made in calendar year 2000. Any reinsurance payments made by the second reinsurance contract would be contingent upon claims arising from the $1.1 billion book of mortgage loans made in calendar year 2002.

Why would the bank have a reinsurance arrangement with the PMI provider?
What does the bank gain by reinsuring some of the risk that has been passed on to the PMI provider? Profits. Private mortgage insurance is generally a very profitable line of business. For example, consider the results reported by one of the largest writers of private mortgage insurance, Mortgage Guaranty Insurance Corporation (MGIC). According to MGIC's financial statements from 1997 through 2001, MGIC's combined ratio from 1993 through 2001 ranged from a low of 26.7% to a high of 66.0% and the company's return on equity was consistently in excess of twenty percent.[1] The bank wants a share of these profits. The bank, through its reinsurance contract with the PMI provider, is able to share in the PMI profits. Of course, by virtue of its re-acquiring some of the default risk that had been passed to the PMI provider, the bank's capital requirement increases. However, the additional capital the bank must hold is less than what it would have had to hold had it not required the mortgagor to purchase PMI. The end result, then, is the PMI provider profits and the bank shares in those profits and uses less capital in the process than if PMI were not used.

D. Aggregation component

This component aggregates balance sheet, income statement and cashflow items from the three operational areas. The aggregation creates financial statements at the holding company level.

E. Economic scenario

An economic scenario generator is used to produce values for various economic indices, including short and long-term interest rates, equity returns, and property inflation. All operational areas of the model access the same economic indices, insuring consistent responses to changes in economic conditions across the modeled environment.

[1] Information taken from MGIC's 1997-2001 annual statements, as posted on their web site http://www.mgic.com/.

III. Risk Factors

The company is exposed to a variety of risk factors, some of which cross multiple operational areas. It is by modeling this commonality of risk factors that the model will derive its ultimate value.

A. Deferred annuity risk factors

The bank is exposed to interest rate risk by selling deferred annuities. As noted in the section above that described the deferred annuity product, the bank pays the deferred annuity investor a contractually specified interest rate. If the bank cannot invest the policyholders' premiums in investments that provide a rate of return at least as high as the rate being paid to policyholders, the company will lose money on the annuity contracts. Additionally, if the deferred annuity policyholders cancel their policies, triggering a repayment requirement on the part of the bank, the bank must liquidate the investments that were purchased with the deferred annuitants' premiums. If the market value of those investments has declined below the repayment requirement, the bank must make up the difference out of surplus. Both of these are examples of an exposure to interest rate risk.

B. Residential mortgage risk factors

The bank is exposed to both interest rate risk and credit risk through its investment in residential mortgages. The interest rate risk arises from the potential for the mortgagors to prepay the mortgage if interest rates decline. This, in turn, puts the bank in the position of having to reinvest the repaid principal at a time when interest rates have declined. The result is that the bank will most likely have to invest in new assets with lower yields than the prepaid mortgages would have yielded, had they not prepaid. The credit risk reflects the potential for mortgagors to default on their loans at a time when the values of the properties securing the mortgages are less than the outstanding mortgage principal balance.

C. Private mortgage insurance risk factors

The PMI provider and the bank, through its reinsurance arrangement with the PMI provider, are both exposed to pricing and interest rate risk factors. The pricing risk arises from the potential that the (re)insurance is improperly priced vis-à-vis the underlying loss exposure arising from the insured mortgages. The underlying loss exposure is the same as the credit risk exposure faced by the bank when providing money for a mortgage that does not require PMI. This is the risk that, once a mortgagor has defaulted on his loan, the property value is worth less than the outstanding loan amount. The interest rate risk exposure is driven by the same factors as the residential mortgage interest rate risk – namely that in a period of declining interest rates, a higher percentage of mortgages will refinance their loans. When the underlying loans are refinanced, the PMI premiums that had been generated by those loans are cut off, leaving the PMI provider with lower than anticipated premium inflows. (The person refinancing the loan may need to purchase PMI on the refinanced loan, however there

is no guarantee that either the refinancing or the reinsuring of the PMI provider will be done by this bank.)

IV. Putting the pieces together

A. Deferred Annuity → Residential Mortgages linkage

A bank must have an inflow of funds before it can loan funds out in the form of residential mortgages. There are many ways in which money can enter a bank. One is capital provided by investors in the bank. Another is through the sale of bonds or other debt instruments to outside parties. A third is by taking in funds through traditional avenues, such as customer deposits. Deferred annuities are very similar to bank certificate of deposits except that one is governed by insurance rules and the other by banking rules. We could have chosen to provide funds inflows into our bank through any of these avenues and in the future we expect we would increase the number of ways for money to flow into the bank. For the purposes of the current model, we have limited ourselves to just the sale of deferred annuities, as this is a new venture for the bank and they want to better understand the capital usage that would be involved in selling deferred annuities.

The primary link, then, between deferred annuities and residential mortgages is that the sale of deferred annuities provides the bank with funds that can be invested in residential mortgages.

A secondary link is through the application of a consistent set of economic conditions. Both deferred annuity products and residential mortgages are impacted by changes in underlying interest rates.

- A drop in interest rates will lead to a larger than anticipated number of mortgage refinancings. The bank will receive the outstanding principal from the refinancings and will need to reinvest the money in lower yielding investments. This will lower the spread between the crediting rate the bank has promised its deferred annuity policyholders and the yield the bank is receiving on the investment of the policyholder premiums, reducing or possibly eliminating the bank's profits from the deferred annuity sales.
- A rise in interest rates might lead the holders of the deferred annuities to cash in their policies so they can move their invested funds into higher yielding products. This will force the bank to sell some of its residential mortgages on the secondary market at a time when interest rates are higher than when the mortgages were originally written. As with bonds, the market value of a mortgage declines when interest rates rise. This means the bank is selling mortgages at a time when the market value of the mortgages is depressed relative to the book value of the mortgages. The bank is exposed to the potential for realized capital losses on the mortgages that must be sold to repay the deferred annuity policyholders. The bank is also exposed to a second potential source of loss in a time of rising interest rates, especially if the rising interest rates are accompanied by declining property values,

as happened in the mid-1980's in Texas (from 1986 to 1989, short term interest rates rose from 6.45% to 8.53% and house values declined by an average of 10%[2])

B. Residential Mortgages → Private Mortgage Insurance linkage

The linkage between the residential mortgages and the private mortgage insurance coverage is that the latter exists to protect the bank's investment in the former. The bank, through its reinsuring of the PMI provider, is electing to take back some of the exposure to loss that would otherwise be eliminated through the use of PMI. With this arrangement, the benefits of integrating the residential mortgage and PMI exposures into one model are quite clear. The actions that will lead to prepayments or losses on the residential mortgage portfolio will have a pass-through impact on the profits and losses of the PMI provider, and through the bank's reinsuring of the PMI provider, back to the bank.

When modeling the PMI business on a stand-alone basis, the following items were set up as inputs to model the gross PMI activity:

- Face value of mortgages being written
- Level of PMI coverage provided for each mortgage type
- PMI premium rate for each mortgage type
- Projected mortgage persistency (the percentage of mortgages on the books at time *t* that will prepay in time *t+1*)
- Expected ultimate loss amount, as a percentage of the face value of the mortgages being written
- Claims payout speed

When modeling the PMI business in conjunction with the residential mortgage business, many of these values are passed from the residential mortgage model to the PMI model. In the linked model, the face value of the mortgages being written is a function of the available cash flow, which is developed from both the amount of new deferred annuities being written and the profits derived across all three operating units. The level of PMI coverage provided for each mortgage type remains an input, but now it is captured as a characteristic of the mortgages being financed in the residential mortgage model. The same is true of the PMI premium rate for each mortgage type. The PMI mortgage persistency is now driven by persistency assumptions in the residential mortgage model. In turn, the residential mortgage persistency calculation is driven by the spread between the interest rate of each mortgage and the interest rate at time *t*. The modeler enters a table of prepayment rates that vary with the spread – the larger the spread, the higher the prepayment percentage.

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[2] Short-term interest rate data was taken from information on the Federal Reserve web site, http://www.federalreserve.gov/releases/. House values data was taken from the house price index compiled by the Office of Federal Housing Enterprise Oversight and provided on their web site, http://www.ofheo.gov/house/index.html.

The most interesting linkage is in the area of defaults and recoveries, which translate to claims against the private mortgage insurance. In the stand-alone PMI model, assumptions were made about the expected ultimate claims amount per $1,000 of mortgage face value and the timing with which the claims would be reported and paid. In the stand-alone residential mortgage application, each mortgage is given a credit rating (AAA, AA, etc.) and there is a user-entered annual default rate associated with each credit rating. The residential mortgage application applies the annual default rate to the outstanding loan balance at the start of each year to develop that year's default amount. Additionally, there is a recovery rate assumed for each credit rating that is used to calculate the percentage of defaulted principal that is recovered whenever there is a default.

In the merged model, both the default and recovery amounts are passed into the PMI model. At this point the recovery amounts are the recoveries that would be made in the absence of the PMI coverage. An additional calculation must occur – the calculation of the PMI claim, which will ultimately impact the recovery amount. The amount of the PMI claim will be the lesser of (a) and (b), where (a) and (b) are:

(a) Difference between default amount and recovery amount being passed from the residential mortgage application
(b) The percentage of the original mortgage portfolio remaining at time *t* * original principal amount of the mortgage portfolio * default rate at time *t* * PMI coverage percentage

Two examples will help to clarify the calculation of the PMI claim.

Example 3

Suppose at time 1, the bank loans $100,000,000 in residential mortgage loans. This can be thought of as 1,000 mortgages of $100,000 each. The next year, ten percent of the mortgages default. For simplicity sake, assume that none of the principal has been repaid yet. This equates to $10,000,000 in defaulted loans. Next, suppose that forty percent of the default amount is recoverable by the bank taking possession of the defaulted property and selling it on the open market. This produces a recovery amount of $4,000,000, or a net loss of $6,000,000.

Furthermore, suppose that PMI coverage exists on each of the mortgages with a thirty percent coverage rate. This exposes the PMI provider to a maximum loss of $30,000 per mortgage (30% of the 100,000 face amount of each mortgage). If we think about the defaults in terms of individual mortgages, there were 100 defaults with a net cost of $60,000 each. The PMI provider will pay the maximum claim amount of $30,000 on each of the defaulted mortgages for a total claim amount of $3,000,000.

In terms of (a) and (b), the calculations would be:

(a) $10,000,000 – 4,000,000 = $6,000,000
(b) Percentage of the original mortgage portfolio remaining = 100%, original principal amount of the mortgage portfolio = 100,000,000, default rate = 10%, PMI coverage percentage = 30%→100% * 100,000,000 * 10% * 30% = $3,000,000

Since (b) is less than (a), the PMI claim amount equals $3,000,000.

Example 4

Suppose we are now at time 20 and we are still looking at the block of mortgages written at time 1. By now, 85% of the original 1,000 mortgages have either prepaid or defaulted and the outstanding principal on the remaining 150 mortgages is $6,000,000, or $40,000 per mortgage. As before, ten percent of the remaining mortgages default and forty percent of default amount is recoverable on the open market. This equates to a $600,000 default amount and a $240,000 recovery amount, or a net loss of $360,000.

The PMI coverage still provides a maximum claim payment of $30,000 per mortgage. However, the PMI provider has the option of paying the mortgagee an amount equal to the outstanding principal balance instead of paying $30,000 per mortgage. If the PMI provider pays the mortgagee $40,000 per defaulted mortgage and recovers $16,000 per defaulted mortgage, the net loss will be $24,000 per mortgage instead of $30,000 per mortgage. Therefore, this is what the PMI provider will do, resulting in a claim amount of $24,000 * 15 = $360,000.

In terms of (a) and (b), the calculations would be:

(a) $600,000 – 240,000 = $360,000

(b) Percentage of the original mortgage portfolio remaining = 15%, original principal amount of the mortgage portfolio = 100,000,000, default rate = 10%, PMI coverage percentage = 30%→15% * 100,000,000 * 10% * 30% = $450,000

Since (a) is less than (b), the PMI claim amount equals $360,000.

The amount of the PMI claim is passed back to the residential mortgage application and added to the amount that would have been recovered in the absence of the PMI claim. Referring back to the two examples above, the following table shows how the recovery amounts are modified in the residential mortgage model:

	Without PMI coverage	With PMI coverage	Net loss to residential mortgage provider
Example 3	$ 4,000,000	$ 7,000,000	$ 3,000,000
Example 4	$ 240,000	$ 600,000	$ 0

C. Private Mortgage Insurance → Bank reinsurance of PMI provider linkage

The bank, through a reinsurance contract with the PMI provider, takes back some of the risk originally assumed by the PMI provider. One such contract might specify that the bank reinsures the PMI provider under a "10 x 5" excess of loss agreement. The 5 refers to five percent of the original risk exposure, so in the terms of Example 3, the

bank would reinsure all claims payments between $1,500,000 and $4,500,000.[3] If the claims in Example 3 and Example 4 were the only claims paid by the PMI provider on this block of mortgages, the bank would have to repay $1,860,000 back to the PMI provider. The cash flow, balance sheet, and income statement values of the bank's reinsuring of the PMI provider all get incorporated into the bank's consolidated financial statements for accounting and tax purposes.

V. Conclusion

As will all papers of this nature, the conclusion begins with "There is much more still to do..." With models of this type, there is always more to do, whether it is refining assumptions, extending the model's scope, incorporating more cross-model linkages, etc. This model is certainly no different. The near term process involves the completion of the work described in this paper and drawing conclusions about capital needs and the volatility of results on an integrated basis and deciding if any changes ought to be made in the bank's strategy for these operations. Longer-term processes involve extending the scope of the model by adding more components that reflect different aspects of the bank's operations and seeing how the model reacts. Model building of this nature is a process that should not be rushed and that is the approach being taken here. It would be interesting to revisit this model in two or three years and see how it has evolved from what it is today.

[3] In Example 3, the PMI provider was exposed to a maximum loss of $30,000 per mortgage x 1,000 mortgages, or $30,000,000. Five percent of $30 million is $1.5 million and ten percent is $3 million. The excess of loss contract attaches at $1.5 million and covers the next $3 million of loss.