Credit crisis in the United States
• The crisis began in August 2007, when a loss of confidence by investors in the value of securitized mortgages in the United States resulted in a liquidity crisis which prompted a substantial injection of capital into financial markets by the United States Federal Reserve and the European Central Bank. The TED spread, an indicator of perceived credit risk in the general economy, spiked up in August 2007, remained volatile for a year, then spiked even higher in September 2008.
• United States housing market collapse is often cited as having caused the crisis. But the financial system was also vulnerable because of credit derivatives - Credit Default Swaps (CDS), which insure debt holders against default, and wide use of Collateralized Debt Obligations. CDS are private transactions, traded over the counter, and are not regulated. Regulatory seizure of companies holding mortgages prompted auctions of their debt so that traders who bought and sold default protection (CDS) could settle contracts. The auctions are used to set a price by which investors can settle the contracts with cash rather than having to physically deliver a bond to their counterparties. Sellers of protection pay the face value of the contracts minus the recovery value set on the bonds.
• The initial liquidity crisis is seen to have resulted from the incipient subprime mortgage crisis. One of the first victims outside the US was Northern Rock, a major British bank. The bank's inability to borrow additional funds to pay off maturing debt obligations led to a bank run in mid-September 2007. This led to its takeover by the British Government and provided an early indication of the troubles that would soon befall other banks and financial institutions.
• Excessive lending under loosened underwriting standards, which was a hallmark of the United States housing bubble, resulted in a very large number of subprime mortgages. These high-risk loans had been perceived to be mitigated by securitization. The damage from these failing securitization schemes eventually cut across a large swath of the housing market and the housing business and led to the subprime mortgage crisis. The accelerating rate of foreclosures caused an ever greater number of homes to be brought for sale onto the market. This glut of homes decreased the value of other surrounding homes which themselves became subject to foreclosure or abandonment.
• Initially the companies affected were those directly involved in home construction and mortgage lending such as Northern Rock and Countrywide Financial. Financial institutions which had engaged in the securitization of mortgages such as Bear Stearns then fell prey. Bear Stearns was acquired by JP Morgan Chase through the deliberate assistance from the US government. Its stock price fell from the record high $154 to $3, which was the initial acquisition price by JP Morgan Chase: subsequently the acquisition price was agreed on $10 between the US government and JP Morgan.
• On July 11, 2008, the largest mortgage lender in the U.S., IndyMac Bank was seized by federal banking regulators.
• On September 7, 2008, Fannie Mae and Freddie Mac were placed into federal conservatorship on September 7, 2008 after the crisis further accelerated.
• The crisis then began to affect the general availability of credit to non-housing related businesses and to larger financial institutions not directly connected with mortgage lending. At the heart of many of these institution's portfolios were investments whose assets had been derived from bundled home mortgages. Exposure to these mortgage-backed securities, or to the credit derivatives used to insure them against failure,

threatened an increasing number of firms such as Lehman Brothers, AIG, Merrill Lynch, and HBOS. Other firms that came under pressure included Washington Mutual, the largest savings and loan association in the United States, and the remaining large investment firms, Morgan Stanley and Goldman Sachs.

• Beginning with bankruptcy of Lehman Brothers on Sunday, September 14, 2008, the financial crisis entered an acute phase marked by failures of prominent American and European banks and efforts by the American and European governments to rescue distressed financial institutions, in the United States by passage of the Emergency Economic Stabilization Act of 2008 and in European countries by infusion of capital into major banks. Afterwards, Iceland entered into severe financial crisis and nationalized its banks, and several countries, including Pakistan, Argentina, and Hungary, indicated liquidity problems and possible inability to make payments on their foreign debt. Many financial institutions in Europe also faced problems with their capital ratios. As the crisis developed, stock markets fell worldwide, and global financial regulators attempted to coordinate efforts to contain the crisis. The US government created a $700 billion plan, which was attempted to purchase the non-performing mortgage assets. The plan was initially stopped in the U.S. Congress because a majority of Republicans rejected the idea that the taxpayers money are used to bail out failed financial institutions. Congress eventually adopted an amended bail out plan. The market sentiment continuously deteriorated nevertheless. While the market turned extremely pessimistic, the British government launched a 500 billion pounds bail out plan aimed to injecting capital into the financial system. The British government nationalized most of the financial institutions in trouble. European governments also created crisis response plans, generally following the methodology of nationalizing troubled financial institutions.

• As the financial panic developed during September and October, 2008 there was a "flight to quality" as investors sought safety in U.S. Treasury debt and currencies such as the dollar and the yen. This currency crisis threatened to disrupt international trade and produced strong pressure on all world currencies.

• The International Monetary Fund also responded to crisis, but it has limited resources relative to the needs of the many nations with currency under pressure or near collapse.

Steps taken by the Federal Reserve to address the Credit Crisis

Addressing the problem of bank panics
• Elastic currency
One way to prevent bank runs is to have a money supply that can expand when money is needed. The term "elastic currency" in the Federal Reserve Act doesn't just mean the ability to expand the money supply, but also to contract it. Some economic theories have been developed that support the idea of expanding or shrinking a money supply as economic conditions warrant. In practice, the Federal Reserve has never contracted the monetary supply since the Great Depression, on the fear that contracting the money supply may cause a deflationary recession, and because according to the operating theory of the Federal Reserve, monetary supply should expand as the economy expands to accommodate larger volumes of transaction.

• Check clearing system
Because some banks refused to clear checks from certain other banks during times of economic uncertainty, which increased financial problems, a check-clearing system was created in the Federal Reserve System.

• Lender of last resort
The Federal Reserve has the authority to act as "lender of last resort" by extending credit to depository institutions or to other entities in unusual circumstances involving a national or regional emergency, where failure to obtain credit would have a severe adverse impact on the economy. Through its discount and credit operations, Reserve Banks provide liquidity to banks to meet short-term needs stemming from seasonal fluctuations in deposits or unexpected withdrawals. Longer-term liquidity may also be provided in exceptional circumstances. The rate the Fed charges banks for these loans is the discount rate (officially the primary credit rate). In making these loans, the Fed serves as a buffer against unexpected day-today fluctuations in reserve demand and supply. This contributes to the effective functioning of the banking system, alleviates pressure in the reserves market and reduces the extent of unexpected movements in the interest rates. For example, on September 16, 2008, the Federal Reserve Board authorized an 85 billion dollar loan to stave off the bankruptcy of international insurance giant American International Group (AIG). The Federal Reserve System's role as lender of last resort is criticized for shifting risk and responsibility away from lenders and borrowers and placing them on others in the form of taxes and/or inflation.

Preventing asset bubbles
The board of directors of each Federal Reserve Bank District also have regulatory and supervisory responsibilities. For example, a member bank (private bank) is not permitted to give out too many loans to people who cannot pay them back. This is because too many defaults on loans will lead to a bank run. If the board of directors has judged that a member bank is performing or behaving poorly, it will report this to the Board of Governors. These aspects of the Federal Reserve System are the parts intended to prevent or minimize speculative asset bubbles, which ultimately lead to severe market corrections.

Interbank lending is the basis of policy
The Federal Reserve implements monetary policy by influencing the interbank lending of excess reserves. Interbank lending occurs when too many withdrawals have been made at a bank and it needs to borrow funds from another bank to make up the difference. The rate that banks charge each other for these loans is determined by the markets but the Federal Reserve influences this rate through the three tools of monetary policy.

Tools
There are three main tools of monetary policy that the Federal Reserve uses to influence the amount of reserves in private banks:

> 1. Open market operations: purchases and sales of U.S. Treasury and federal agency securities—the Federal Reserve's principal tool for implementing monetary policy. The Federal Reserve's objective for open market operations has

varied over the years. During the 1980s, the focus gradually shifted toward attaining a specified level of the federal funds rate (the rate that banks charge each other for overnight loans of federal funds, which are the reserves held by banks at the Fed), a process that was largely complete by the end of the decade.
2. Discount rate: the interest rate charged to commercial banks and other depository institutions on loans they receive from their regional Federal Reserve Bank's lending facility--the discount window.
3. Reserve requirements: the amount of funds that a depository institution must hold in reserve against specified deposit liabilities.

New facilities
In order to address problems related to the subprime mortgage crisis and United States housing bubble, several new tools have been created. The first new tool, called the *Term Auction Facility*, was added on December 12, 2007. It was first announced as a temporary tool but there have been suggestions that this new tool may remain in place for a prolonged period of time. Creation of the second new tool, called the *Term Securities Lending Facility*, was announced on March 11, 2008. The main difference between these two facilities is that the Term Auction Facility is used to inject cash into the banking system whereas the Term Securities Lending Facility is used to inject Treasury securities into the banking system. Creation of the third tool, called the *Primary Dealer Credit Facility (PDCF)*, was announced on March 16, 2008. The PDCF was a fundamental change in Federal Reserve policy because now the Fed is able to lend directly to primary dealers, which was previously against Fed policy. The differences between these 3 new facilities is described by the Federal Reserve as follows:
• The Term Auction Facility program offers term funding to depository institutions via a bi-weekly auction, for fixed amounts of credit.
• The Term Securities Lending Facility will be an auction for a fixed amount of lending of Treasury general collateral in exchange for eligible AAA/Aaa rated private-label residential mortgage-backed securities.
• The Primary Dealer Credit Facility now allows eligible primary dealers to borrow at the existing Discount Rate for up to 120 days.
Some of the measures taken by the Federal Reserve to address this mortgage crisis haven't been used since The Great Depression.

Term auction facility
The Term Auction Facility is a program in which the Federal Reserve auctions term funds to depository institutions. The creation of this facility was announced by the Federal Reserve on December 12, 2007 and was done in conjunction with the Bank of Canada, the Bank of England, the European Central Bank, and the Swiss National Bank to address elevated pressures in short-term funding markets. The reason it was created is because banks were not lending funds to one another and banks in need of funds were refusing to go to the discount window. Banks were not lending money to each other because there was a fear that the loans would not be paid back. Banks refused to go to the discount window because it is usually associated with the stigma of bank failure. Under the Term Auction Facility, the identity of the banks in need of funds is protected in order to avoid the stigma of bank failure. Foreign exchange swap lines with the European

Central Bank and Swiss National Bank were opened so the banks in Europe could have access to U.S. dollars. The TAF is a credit facility that allows a depository institution to place a bid for an advance from its local Federal Reserve Bank at an interest rate that is determined as the result of an auction. By allowing the Federal Reserve to inject term funds through a broader range of counterparties and against a broader range of collateral than open market operations, this facility could help ensure that liquidity provisions can be disseminated efficiently even when the unsecured interbank markets are under stress. In short, the TAF will auction term funds of approximately one-month maturity. All depository institutions that are judged to be in sound financial condition by their local Reserve Bank and that are eligible to borrow at the discount window are also eligible to participate in TAF auctions. All TAF credit must be fully collateralized. Depositories may pledge the broad range of collateral that is accepted for other Federal Reserve lending programs to secure TAF credit. The same collateral values and margins applicable for other Federal Reserve lending programs will also apply for the TAF.

Term securities lending facility
The Term Securities Lending Facility is a 28-day facility that will offer Treasury general collateral to the Federal Reserve Bank of New York's primary dealers in exchange for other program-eligible collateral. It is intended to promote liquidity in the financing markets for Treasury and other collateral and thus to foster the functioning of financial markets more generally. Like the Term Auction Facility, the TSLF was done in conjunction with the Bank of Canada, the Bank of England, the European Central Bank, and the Swiss National Bank. The resource allows dealers to switch debt that is less liquid for U.S. government securities that are easily tradable. It is anticipated by Federal Reserve officials that the primary dealers, which include Goldman Sachs Group. Inc., Bear Stearns Cos. and Merrill Lynch & Co., will lend the Treasuries on to other firms in return for cash. That will help the dealers finance their balance sheets. The currency swap lines with the European Central Bank and Swiss National Bank were increased.

Primary dealer credit facility
The Primary Dealer Credit Facility (PDCF) is an overnight loan facility that will provide funding to primary dealers in exchange for a specified range of eligible collateral and is intended to foster the functioning of financial markets more generally. This new facility marks a fundamental change in Federal Reserve policy because now primary dealers can borrow directly from the Fed when this previously was not permitted.

Interest on reserves
As of October 2008, the Federal Reserve banks will pay interest on reserve balances (required & excess) held by depository institutions. The rate is set at the lowest federal funds rate during the reserve maintenance period of an institution, less 75bps. As of October 23, 2008, the Fed has lowered the spread to 35 bps.

Asset Backed Commercial Paper Money Market Mutual Fund Liquidity Facility (AMLF)
Borrower Eligibility:
All U.S. depository institutions, bank holding companies (parent companies or U.S.

broker-dealer affiliates), or U.S. branches and agencies of foreign banks are eligible to borrow under this facility pursuant to the discretion of the FRBB. Eligible Collateral must meet the following criteria: was purchased by Borrower on or after September 19, 2008 from a registered investment company that holds itself out as a money market mutual fund; was purchased by Borrower at the Fund's acquisition cost as adjusted for amortization of premium or accretion of discount on the ABCP through the date of its purchase by Borrower; is rated at the time pledged to FRBB, not lower than A1, F1, or P1 by at least two major rating agencies or, if rated by only one major rating agency, the ABCP must have been rated within the top rating category by that agency; was issued by an entity organized under the laws of the United States or a political subdivision thereof under a program that was in existence on September 18, 2008; has a stated maturity that does not exceed 120 days if the Borrower is a bank or 270 days for non-bank Borrowers.

Commercial Paper Funding Facility (CPFF)
On October 7, 2008 the Federal Reserve further expanded the collateral it will loan against, to include commercial paper. The action made the Fed a crucial source of credit for non-financial businesses in addition to commercial banks and investment firms. Fed officials said they'll buy as much of the debt as necessary to get the market functioning again. They refused to say how much that might be, but they noted that around $1.3 trillion worth of commercial paper would qualify. There was $1.61 trillion in outstanding commercial paper, seasonally adjusted, on the market as of October 1, 2008, according to the most recent data from the Fed. That was down from $1.70 trillion in the previous week. Since the summer of 2007, the market has shrunk from more than $2.2 trillion.

Money Market Investor Funding Facility (MMIFF)
The Federal Reserve introduced a facility on October 21, 2008, whereby money market mutual funds can setup a structured investment vehicle of short-term assets which will be underwritten by the Federal Reserve Bank of New York. The program will run until April 30, 2009, unless extended by the FRB.

Steps undertaken by the Federal Government to address the credit crisis
• The *Economic Stimulus Act of 2008* was an Act of Congress providing for several kinds of economic stimuli intended to boost the United States economy in 2008 and to avert or ameliorate a recession. The stimulus package was passed by the U.S. House of Representatives on January 29, 2008, and in a slightly different version by the U.S. Senate on February 7, 2008. The Senate version was then approved in the House the same day. It was signed into law by President George W. Bush on February 13, 2008. The law provides for tax rebates to low- and middle-income U.S. taxpayers, tax incentives to stimulate business investment, and an increase in the limits imposed on mortgages eligible for purchase by government-sponsored enterprises (e.g., Fannie Mae and Freddie Mac). The total cost of this bill was projected at $152 billion for 2008. The law offered businesses a one-time depreciation tax deduction equal to 50% of the cost of specified kinds of new investment during 2008. Qualifying investments include tangible property, such as industrial or business equipment, expected to remain in use for less than 20 years, purchased computer software, water utility property, and qualified leasehold improvements. The law also raises the limits on the value of new productive capital

(machinery, equipment, and some other types of property) that businesses may exclude from their income as business expenses during 2008. Previously, the limit on expensable productive capital investments had been $128,000, reduced (but not below zero) by the amount by which the value of those investments exceeded $510,000. The law raises those limits to $250,000 and $800,000 respectively. The law does not change the requirement that expensed investments cannot exceed a business's income to be claimed as a loss.

Emergency Economic Stabilization Act of 2008
Commonly referred to as a **bailout of the U.S. financial system**, is a law enacted in response to the global financial crisis of 2008 authorizing the United States Secretary of the Treasury to spend up to US$700 billion to purchase distressed assets, especially mortgage-backed securities, and make capital injections into banks. The bailed-out banks are mostly U.S. or foreign banks, though the Federal Reserve extended help to American Express, whose bank-holding application it recently approved. The Act was proposed by Treasury Secretary Henry Paulson during the global financial crisis of 2008. The original proposal was three pages, as submitted to the United States House of Representatives. The purpose of the plan was to purchase bad assets, reduce uncertainty regarding the worth of the remaining assets, and restore confidence in the credit markets. The text of the proposed law was expanded to 110 pages and was put forward as an amendment to original bill. The amendment was rejected via a vote of the House of Representatives on September 29, 2008, by a margin of 228-205. On October 1, 2008, the Senate debated and voted on an amendment to another bill, which substituted a newly revised version of the Emergency Economic Stabilization Act of 2008. The Senate accepted the amendment and passed the entire amended bill by a vote of 74-25. Additional unrelated provisions added an estimated $150 billion to the cost of the bill and increased the size of the bill to 451 pages. The amended version of the bill was sent to the House for consideration, and on October 3, the House voted 263-171 to enact the bill into law. President Bush signed the bill into law within hours of its enactment, creating a $700 billion Troubled Assets Relief Program to purchase failing bank assets.

The American Recovery and Reinvestment Act of 2009
Economic stimulus package enacted by the 111th United States Congress and signed into law by President Barack Obama on February 17, 2009.

Provisions of the Act
• Tax cuts: for individuals (small tax credit for payroll taxes, expanded tax credit for children, car purchases), for companies (easier recognition of losses).
• Health Care: Additional funding for Medicare and Medicaid.
• Education: Grants for university education costs, tax credit for university education costs, more funding for Head Start.
• Environment: More funding for environmental cleanup.
• Aid to low income workers, unemployed and retirees (including job training): Expansion of unemployment benefits, one time payment to retirees.
• Infrastructure Investment:
      Core investments (roads, bridges, railways, sewers, other transportation)

Investment into government facilities and vehicle fleets
Supplemental investments
• Energy: Tax credits in non-fossil fuel energy generation and energy conservation.
• Housing: Funding for low-income public housing, additional tax benefits for home purchases.
• Scientific research: NASA, National Science Foundation.
• Other: Block grants to the states.

Failure of bank Basel II RBC approach: Value at Risk (parametric, simulation, or historical approach)
Example of parametric VaR calculation
Given the following information about Portfolios A and B:
• The value of Portfolio A is $15 million and consists only of Company A stock.
• The daily volatility of Portfolio A is 3%.
• The value of Portfolio B is $7 million and consists only of Company B stock.
• The daily volatility of Portfolio B is 2%.
• The correlation coefficient between Company A and Company B stock prices is 0.40.
Calculate the 10-day 99% Value at Risk for a portfolio consisting of Portfolios A and B.

Solution.
The daily volatility of A is 3% of $15 million, or $450,000, and the daily volatility of B is 2% of $7 million, or $140,000. Since the 99-th percentile of the standard normal distribution is 2.33, the quantity sought is

$$2.33 \cdot \sqrt{10} \cdot \sqrt{450000^2 + 140000^2 + 2 \cdot 0.40 \cdot 450000 \cdot 140000} \approx 3846264.75.$$

Solvency II RBC
The SCR is intended to reflect all quantifiable risks that the firm might face, including:
- • non-life underwriting risk
- • life underwriting risk
- • special health underwriting risk
- • market risk
- • credit risk
- • operational risk
It will correspond to the value-at-risk of the net assets (i.e., capital, owners' equity) of the firm subject to a confidence level of 99.5% over a one-year period, assuming continued solvency.

Firms can calculate the SCR in one of two ways:
• use of the standard formula
• use of an internal or partial internal model
The standard formula has a module for each of the above risk types. An SCR for each risk-type (except operational risk) is calculated, with each module calibrated to the "one-year 99.5%" level. The results are then aggregated, with diversification effects governed by a correlation matrix. A separate loading for operational risk (details to be decided) is then added.

U.S. Insurance RBC

The (United States) National Association of Insurance Commissioners (NAIC) instituted its RBC system for life insurance companies in 1993, followed by a property-casualty system in 1994 and a health system in 1998. The NAIC's RBC system consists of two parts:

- A formula that is used to set a regulatory minimum capital level for each insurer, based on that insurer's mix of assets, liabilities, and risk, and
- Definition of "financial impairment" and remedies to state insurance regulators in the event that an insurer meets that definition of impairment.

Formulas continuously evolve. NAIC publishes newsletters and guidelines for the calculation of Risk-Based Capital. The RBC system is meant to be a supplement, not a replacement, for the existing fixed minimum capital requirements that exist in each state. That is, the RBC formula requirements can be higher or lower than the fixed minimum capital requirements (which are typically $1 to $2 million), but each insurance company must meet both sets of standards. Many small insurance companies generate RBC requirements that are lower than the fixed dollar minimums, but for virtually all medium-sized and large insurers, the capital requirements generated by the RBC formula are higher than the state fixed minimums.

The RBC requirement (level of capital required in view of risk undertaken) is calculated by multiplying risk factors by statement values, adding the results together, and then adjusting for covariance between major risk categories. The formula results are compared to the risk-adjusted capital of the insurer to develop the RBC ratio, which is the ratio of risk-adjusted capital to RBC. The ratio results are used to determine the degree to which an insurance company's surplus is impaired. The model act specifies a series of increasingly stringent regulatory responses, as the RBC ratio decreases below 200%. A trend test is included to test whether insurers that were between the 200% breakpoint and 250% level were trending downward, which will trigger regulatory action, but an RBC ratio over 250% for a life company is sufficient to receive a passing grade on this pass/fail test.

There are four "action levels" under the NAIC RBC system.

- Company Action Level (CAL). If this level is reached, insurer is required to automatically submit a written, detailed business plan within 45 days that details the causes and actions that have led up to the capital impairment as well as a plan for the restructuring of the insurer's business to rebuild capital to acceptable levels. Alternatively, the company can detail plans to reduce its risk to a level commensurate with its actual capital level.
- Regulatory Action Level (RAL). In this case, insurer must conform to the requirements stated in the Company Action Level, and in addition is subject to an immediate regulatory audit. The regulator can then issue protective orders to force the insurer to either lower its risk profile or increase its capital to a level commensurate with its risk. A company that has reached the Company Action Level and that does not conform to the statutory requirements spelled out in the statute is also automatically deemed to have triggered the Regulatory Action Level.

- Authorized Control Level (ACL) is triggered by having statutory capital that is less than the Authorized Control Level RBC, as computed by the RBC formula or by failing to meet regulatory requirements imposed by the Regulatory Action Level. The Authorized Control Level is the capital level at which the state insurance commissioner is authorized, although not required, to place the insurance company under regulatory supervision.
- Mandatory Control Level. When that happens, the state regulator is required by statute to take steps to place the insurer under regulatory supervision.

Risk categories in the Life RBC formula
Originally, the major risk categories in the Life RBC formula were C1 – Asset Risk, C2 – Insurance Risk, C3 – Interest Rate Risk and C4 – Business Risk. These generic categories have been later refined and currently they are:

C0	Affiliates Risk
C1cs	Asset Risk – Unaffiliated Common Stock
C1o	Asset Risk – Other Assets Risk
C2	Insurance Risk
C3a	Interest Rate Risk
C3b	Health Credit Risk
C4a	General Business Risk
C4b	Administrative Expense Risk

Major categories in property/casualty RBC formula:
- R0 – Subsidiary Insurers Risk
- R1 – Fixed Income Asset Risk
- R2 – Equity Asset Risk
- R3 – Credit Risk
- R4 – Insurance Risk – Reserve Development
- R5 – Insurance Risk – Written Premiums

Major categories in health RBC formula:
- H0 – Insurance Subsidiaries Risk
- H1 – Asset Risk
- H2 – Insurance Risk
- H3 – Credit Risk
- H4 – Business and Admin Expense Risk

RBC treatment of an affiliate
- RBC calculated by affiliate
- Parent RBC charge equal to its prorated share of affiliate's RBC
  - 100% ownership = 100% rollup of RBC
  - 50% ownership = 50% rollup of RBC
- Treats affiliate as an extension of parent

The values calculated for each category are then combined in what is commonly called the *covariance formula*.

The results of the covariance formula produce the Company Action Level RBC capital requirement. The Company Action Level requirement is twice the Authorized Control Level requirement.

If the insurer's Total Adjusted Capital is less than the Authorized Control Level RBC requirement, the regulator is authorized to seize control of the company. The ACL RBC and the Total Adjusted Capital are both reported in the Five-Year History page of the annual statement. The RBC formula inputs and calculations are not made public.

Total Adjusted Capital =
Statutory Capital & Surplus + Asset Valuation Reserve (AVR) including AVR in separate accounts + Half of company's liability for dividends + company's ownership share of AVR of subsidiaries + Half of company's ownership share of subsidiaries' dividend liability

Separate risk-based capital models apply to life companies, property/casualty companies and health organizations. The common risks identified in the NAIC models for all types of companies include Asset Risk-Affiliates, Asset Risk-Other, Credit Risk, Underwriting Risk, and Business Risk.

Asset risk (C1) calculation example:
Note: Risk factors are developed by an NAIC Advisory Group. Based on simulation testing for portfolios of bonds. They are intended to account for default risk only. In what follows we use factors that may not be exactly the ones currently used.

Asset portfolio given:		Factor	RBC
NAIC Class 1, U.S. Government	$1000	0.000	$0.00
NAIC Class 1, non-U.S. Government	$1000	0.003	$3.00
NAIC Class 2	$1000	0.010	$10.00
NAIC Class 3	$1000	0.020	$20.00
NAIC Class 4	$1000	0.045	$45.00
NAIC Class 5	$1000	0.100	$100.00
NAIC Class 6	$1000	0.300	$300.00
Total	$7000		$478.00

There is then a bond size adjustment factor, i.e., the resulting RBC is multiplied by a number f_{SIZE}, which is determined by the number of bonds in the portfolio. Note: there are no adjustments for portfolio size for stocks and mortgages.

For stocks, the C1 RBC is derived by multiplying the total value of all stocks by a factor provided by NAIC (30% for life companies, 15% for property/casualty companies, but note that factors may change over time).

Life mortgages formula is based on Asset Valuation Reserve (AVR)
- Mortgage Experience Adjustment (MEA)
- Separate Risk Factors By Mortgage Type
  - Farm
  - Residential

- o Commercial
  - o Restructured
- Separate Risk Factors By Quality
  - o In Good Standing
  - o Overdue
  - o In Foreclosure

Life real estate formula:
- Separate calculations for each property, then add up to get the total.
- Large number of separate RBC factors depending on type and quality of property, very complex.
- Questionable accuracy.

Accounting for insurance risk C2:
- Life formula uses tiered factors to adjust for size differences.
- Life insurance - Apply factors against net amount at risk.
- Health insurance - Apply factors against earned premiums.
- Flat factor is applied against health insurance reserves (e.g., not size-based).
- Credit allowed for premium stabilization reserves.

Example of tiered premium insurance risk RBC calculation:
A company has $10,000,000 in net amount at risk. A factor of 3.5% is applied to the first $5 million, and 2.0% for the next $5 million. Then the insurance risk RBC for this company is: 3.5% of $5,000,000 plus 2.0% of $5,000,000, for a total of $175,000 + $100,000 = $275,000.

C4 RBC is calculated generally as a small percentage of premiums, in the range of 2%.

C3 RBC calculation has gradually evolved with C3 Phase III implemented effective January 1, 2010.

(1). Project asset and liability cash flows using Prudent Estimate Assumptions over a series of stochastically generated interest rate and/or equity return scenarios calculating the net accumulated asset amount (projected statement value of invested assets).

(2). Calculate the accumulated deficiency at the end of each projection year. The accumulated deficiency is the excess of the cash surrender value (zero is used for products that do not have a cash surrender value) over the net accumulated asset amount.

(3). For each scenario, calculate the present value of each accumulated deficiency and determine the greatest present value.

(4). The Scenario Amount is the sum of the statement value of starting assets and the greatest present value for that scenario.

(5). Determine the Stochastic Amount by calculating the CTE 90 value of the Scenario Amounts by taking the average of the highest 10% of the Scenario Amounts.

Steps in RBC calculation:
- Apply risk factors against annual statement values,
- Sum risk amounts and adjust for statistical independence (using the covariance formula),
- Calculate Authorized Control Level Risk-Based Capital amount,
- Compare ACL RBC to Adjusted Capital.

Total Adjusted Capital (Actual Capital) is divided by Authorized Control Level RBC (Hypothetical Minimum Capital) to get the RBC Ratio
- No Action (98% of companies) -- TAC/RBC over 200%
- Company Action Level -- TAC/RBC is 150% to 200%
- Regulatory Action Level -- TAC/RBC is 100% to 150%
- Authorized Control Level -- TAC/RBC is 70% to 100%
- Mandatory Control Level -- TAC/RBC is less than 70%

After the calculation of RBC, the company is also expected to perform sensitivity tests to indicate how sensitive the results are to certain risk factors' changes.

Comparison of the NAIC Life, P&C

Life RBC

C0	Insurance affiliate investment and (non-derivative) off-balance sheet risk
C1cs	Invested common stock asset risk
C1o	Invested asset risk, plus reinsurance credit risk except for assets in C1cs
C2	Insurance risk
C3a	Interest rate risk
C3b	Health provider credit risk
C4a	Business risk - guaranty fund assessment and separate account risks
C4b	Business risk - health administrative expense risk

Company action level RBC =
$$C0 + [(C1o + C3a)^2 + (C1cs)^2 + (C2)^2 + (C3b)^2 + (C4b)^2]^{1/2} + C4a$$

P&C RBC

R0	Insurance affiliate investment and (non-derivative) off-balance sheet risk
R1	Invested asset risk - fixed income investments
R2	Invested asset risk - equity investments
R3	Credit risk (non-reinsurance plus one half reinsurance credit risk)
R4	Loss reserve risk, one half reinsurance credit risk, growth risk
R5	Premium risk, growth risk

Company action level RBC =
$$R0 + [(R1)^2 + (R2)^2 + (R3)^2 + (R4)^2 + (R5)^2]^{1/2}$$

Health RBC

H0	Insurance affiliate investment and (non-derivative) off-balance sheet risk
H1	Invested asset risk
H2	Insurance risk
H3	Credit risk (health provider, reinsurance, misc. receivables)
H4	Business risk (health administrative expense risk, guaranty fund assessment risk, excessive growth)

Company action level RBC =
$$H0 + [\,(H1)^2 + (H2)^2 + (H3)^2 + (H4)^2\,]^{1/2}$$

Exercise

Regulated Insurance is a company domiciled in Freedonia, a country that implemented a risk-based capital requirement system for regulation of its insurance companies. Risk-based capital requirement is the amount equal to the 95-th percentile of random amount of the loss that the company experiences in one year. The company has liabilities of 1,000,000 freebies (the currency of Freedonia) in life annuities reserves, and assets of $1,200,000 freebies, invested 40% in stocks and 60% in bonds. The liabilities of the company will increase by 3% over the next year. The effective annual rate of return on bonds follows a normal distribution with mean 4% and standard deviation of 2%, while the effective annual rate of return on stocks follows a normal distribution with mean 9% and standard deviation of 12%. The correlation of returns of stocks and bonds is 0.6, and the joint distribution of returns of stocks and bonds is bivariate normal. Find the ratio of the capital held by Regulated Insurance to the capital required by regulation in Freedonia. The 95-th percentile of the standard normal distribution is 1.645.

Solution.

The capital held by Regulated Insurance is equal to the excess of its assets over its liabilities, i.e., 1,200,000 − 1,000,000 = 200,000 freebies. Let X be the random rate of return of stocks, and Y be the random rate of return on bonds. The loss of Regulated Insurance in one year is

$$0.03 \cdot 1000000 - X \cdot 0.4 \cdot 1200000 - Y \cdot 0.6 \cdot 1200000 =$$

$$= 30000 - 480000\,X - 720000\,Y.$$

This is a normal random variable with mean

$$E\left(30000 - 480000\,X - 720000\,Y\right) = 30000 - 19200 - 64800 = -54000,$$

and variance

$$\mathrm{Var}\left(30000 - 480000\,X - 720000\,Y\right) = \mathrm{Var}\left(480000\,X + 720000\,Y\right) =$$

$$= 480000^2 \cdot 0.12^2 + 720000^2 \cdot 0.02^2 + 480000 \cdot 720000 \cdot 0.12 \cdot 0.02 \cdot 0.7 =$$

$$= 4105728000.$$

The 95-th percentile of the distribution is $-54000 + 1.645 \cdot \sqrt{4105728000} \approx 51404.9459$.

The ratio sought is $\dfrac{200000}{51404.9459} \approx 3.8907$.

Exercise.
Honorable Life Insurance Co. (HLIC) is headquartered in Freedonia, a country that just established new Risk-Based Capital regulation. Required capital equals

$$C_R = 1.25\sqrt{(C_1 + C_3)^2 + C_2^2},$$

where:
• C_1 = capital requirement for asset portfolio, equal to the sum of 20% of the value of stock portfolio held and 2% of the value of the bond portfolio held. Companies in Freedonia only invest in stocks or bonds.
• C_2 = capital requirements for liabilities, equal to 1% of amount at risk, defined as the difference between the amount of insurance and the liability established for it.
• C_3 = capital requirement for asset-liabilities interaction, set as the change in the value of the surplus as a result in the increase of interest rate of 100 basis points, calculated with the standard duration-convexity approximation.
You are given the following:
• HICS portfolio is always invested 20% in stocks and 80% in bonds, and its asset portfolio is worth 1,100,000 freebies, the currency in Freedonia. If assets are sold, stocks and bonds are sold proportionately, so that the allocation of 20% in stocks and 80% in bonds is retained.
• The liabilities are one million freebies and the net amount at risk is also one million freebies.
• The company's surplus has the duration of 20 years and convexity of 100 years squared. HLIC can purchase a proportional reinsurance, in which it receive credit for a fraction w of its liabilities, and covering the same fraction of insurance amount, costing 105% of the amount of liabilities reinsured. Assume that the duration and convexity of the surplus is unchanged by the reinsurance contract. Calculate the smallest w such that the reinsurance the company purchases causes it to have the capital that is greater than or equal to the capital required.

Solution.
Before reinsurance, the company has
　　　Assets of 1,100,000 consisting of 220,000 in stocks and 880,000 in bonds,
　　　Liabilities of 1,000,000, and amount of insurance of 2,000,000,
　　　Surplus of 100,000.
Also before reinsurance, risk-based capital calculation is as follows
$$C_1 = 0.2 \cdot 220,000 + 0.02 \cdot 880,000 = 61600,$$
$$C_2 = 0.01 \cdot 1,000,000 = 10000,$$
$$C_3 = -\left(-100,000 \cdot 0.01 \cdot 20 + \frac{1}{2} \cdot 100,000 \cdot 0.01^2 \cdot 100\right) = 19,500,$$
$$C_R = 1.25\sqrt{(61600 + 19500)^2 + 10000^2} \approx 102,142.746.$$
But the company only has the capital of 100,000 freebies, so it is failing the regulatory requirements. If the company purchases reinsurance for a fraction w of its liabilities, it will have
　　　Assets of $1100000 - 1050000w = 1100000(1-w) + 50000w$

invested 20% in stocks and 80% in bonds,
Liabilities of $1000000(1-w)$
and amount of insurance of $2000000(1-w)$,

Surplus of
$$\left(1100000(1-w)+50000w\right)-\left(1000000(1-w)\right)=$$
$$=100000(1-w)+50000w=100000-50000w.$$

Risk-based capital calculation is as follows
$$C_1 = 0.2\cdot 220{,}000(1-w)+0.2\cdot 0.2\cdot 50000w+$$
$$+0.02\cdot 880{,}000(1-w)+0.02\cdot 0.8\cdot 50000w=$$
$$=61600(1-w)+2800w=61600-58800w,$$
$$C_2 = 0.01\cdot 1{,}000{,}000(1-w)=10000(1-w),$$

$C_3 =$
$$=-\left(-\left(100000(1-w)+50000w\right)\cdot 0.01\cdot 20+\left(100000(1-w)+50000w\right)\cdot \frac{1}{2}\cdot 0.01^2\cdot 100\right)=$$
$$=19{,}500(1-w)+10250w=19500-9250w,$$

and
$$C_R = 1.25\sqrt{\left(61600-58800w+19500-9250w\right)^2+\left(10000(1-w)\right)^2}=$$
$$=1.25\sqrt{\left(81100-68050w\right)^2+\left(10000(1-w)\right)^2}.$$

The capital held and capital required will be equal if
$$100000-50000w=1.25\sqrt{\left(81100-68050w\right)^2+\left(10000(1-w)\right)^2},$$

or
$$\left(80000-40000w\right)^2=\left(81100-68050w\right)^2+\left(10000(1-w)\right)^2.$$

We solve this equation
$$0=\left(10000(1-w)\right)^2+\left(81100-68050w\right)^2-\left(80000-40000w\right)^2=$$
$$=10000^2\cdot\left(1-2w+w^2\right)+\left(1100-28050w\right)\left(161100-108050w\right)=$$
$$=3130802500w^2-4837710000w+27721000,$$

as
$$w=\frac{4837710000\pm\sqrt{4837710000^2-4\cdot 3130802500\cdot 27721000}}{2\cdot 3130802500}\approx\begin{cases}1.4856,\\0.0596.\end{cases}$$

Since it is not possible to reinsure more than 100% of policies issued, only the second solution is feasible, and the answer is $w=0.0596=5.96\%$.

Exercise.
You are the Investment Actuary for the Brave Property/Casualty Insurance Company, which invests all of its assets, worth $30 million, in a risk-free bond earning 3%. Liabilities are uncertain and vary according to the following risk-neutral probability distribution:

Amount to be paid in one year	Risk-Neutral Probability
$100 million	1%
$50 million	4%
$10 million	95%

The regulators in Freedonia, where the Brave Property/Casualty Insurance Company is located, introduce a new regulatory requirement for a risk-based capital. Required amount of capital is defined as follows:

• The company must calculate the market value of its liabilities, and create an asset-liability portfolio consisting of its liabilities and assets equal to them in value. For that asset-liability portfolio, initial surplus is zero.

• Then the company must establish the probability distribution of the surplus of that asset-liability portfolio in one year. The conditional expected value of that surplus, given that it is greater than or equal to the 95-th percentile of its distribution, then must be calculated.

• The actual surplus of the company, with risk-free interest earned through the end of the year, must be sufficient to cover the conditional expected value calculated.

Calculate the additional amount of capital the company must raise in order to meet the new capital requirements.

Solution.

The market value of the liabilities, in millions of dollars, is:
$$\frac{100 \cdot 0.01 + 50 \cdot 0.04 + 10 \cdot 0.95}{1.03} \approx 12.14.$$

This amount of assets is assigned to the asset-liability portfolio. In one year, those assets accumulate to:
$$1.03 \cdot \frac{100 \cdot 0.01 + 50 \cdot 0.04 + 10 \cdot 0.95}{1.03} = 12.5.$$

The probability distribution of the asset-liability portfolio in one year is:

Amount in one year ($ million)	Risk-Neutral Probability
100 – 12.5 = 87.5	1%
50 – 12.5 = 37.5	4%
10 – 12.5 = –2.5	95%

The 95-th percentile of this distribution is 37.5, and the conditional expected value is
$$87.5 \cdot \frac{0.01}{0.05} + 37.5 \cdot \frac{0.04}{0.05} = 47.5.$$

The actual surplus that the company has is 30 – 12.5 = 17.5. This means that the company must raise additional 30 million dollars of capital.