- American ESO with Vesting and Suboptimal Exercise Behavior.
- American ESO with Vesting, Suboptimal Exercise Behavior, Blackout Periods, and Forfeiture Rate.

Each option is discussed in detail followed by simple case studies and solutions using the SLS software. Additional study questions and hands-on exercises are also included at the end of each case study. Chapter 11's case studies are more detailed and protracted, and are focused on understanding how the real options analysis process works, whereas this chapter's short cases are focused on how the real options computations and software work.

AMERICAN, EUROPEAN, BERMUDAN, AND CUSTOMIZED ABANDONMENT OPTION

The *Abandonment Option* looks at the value of a project's or asset's flexibility in being abandoned over the life of the option. As an example, suppose that a firm owns a project or asset and that based on traditional discounted cash flow (DCF) models, it estimates the present value of the asset (*PV Underlying Asset*) to be $120M (for the abandonment option this is the net present value of the project or asset). Monte Carlo simulation using the Risk Simulator software indicates that the *Volatility* of this asset value is significant, estimated at 25 percent. There is a lot of uncertainty as to the success or failure of this project (the volatility calculated models the different sources of uncertainty and computes the risks in the DCF model including price uncertainty, probability of success, competition, cannibalization, etc.), and the value of the project might be significantly higher or significantly lower than the expected value of $120M. Suppose an abandonment option is created whereby a counterparty is found and a contract is signed that lasts five years (*Maturity*) such that for some monetary consideration now, the firm has the ability to sell the asset or project to the counterparty at any time within these five years (indicative of an American option) for a specified *Salvage* of $90M. The counterparty agrees to this $30M discount and signs the contract.

What has just occurred is that the firm bought itself a $90M insurance policy. That is, if the asset or project value increases above its current value, the firm may decide to continue funding the project, or sell it off in the market at the prevailing fair market value. Alternatively, if the value of the asset or project falls below the $90M threshold, the firm has the right to execute the option and sell off the asset to the counterparty at $90M. In other words, a safety net of sorts has been erected to prevent the value of the asset from falling below this salvage level. Thus, how much is this safety net or insurance policy worth? One can create competitive advantage in negotiation if the counterparty does not have the answer and you do. Further assume that the five-year Treasury note *Risk-Free Rate* (zero coupon) is 5 percent from the U.S. Department of Treasury (http://www.treas.gov/offices/domestic-finance/debt-management/interest-rate/yield-hist.html). The *American Abandonment Option* results in Figure 10.1 show a value of $125.48M, indicating that the option value is $5.48M as the present value of the asset is $120M. Hence, the *maximum* value one should be willing to pay for the contract on *average* is $5.48M. This resulting expected value weights the continuous probabilities that the asset value exceeds $90M versus when it does not (where the abandonment option is valuable). Also, it weights when the timing of executing the abandonment is optimal such that the expected value is $5.48M.

In addition, some experimentation can be conducted. Changing the salvage value to $30M (this means a $90M discount from the starting asset value) yields a result of $120M, or $0M for the option. This result means that the option or contract is worthless because the safety net is set so low that it will never be utilized. Conversely, setting the salvage level to thrice the prevailing asset value or $360M would yield a result of $360M, and the options

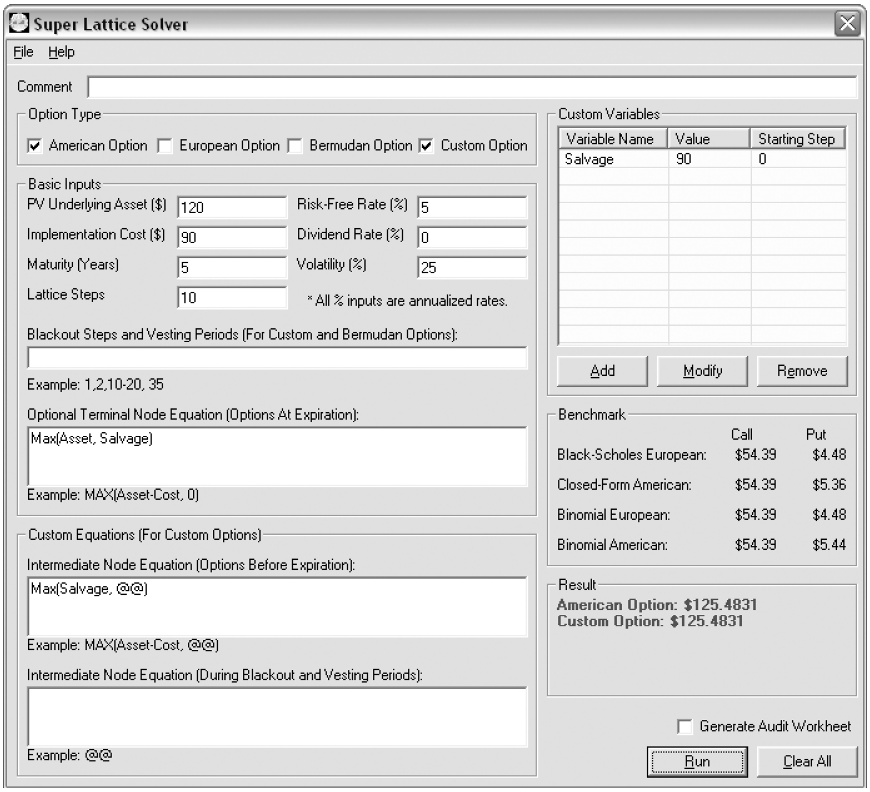

FIGURE 10.1 Simple American Abandonment Option

valuation results indicate $360M, which means that there is no option value, there is no value in waiting and having this option, or simply, execute the option immediately and sell the asset if someone is willing to pay three times the value of the project right now. Thus, you can keep changing the salvage value until the option value disappears, indicating the *optimal trigger value* has been reached. For instance, if you enter $166.80 as the salvage value, the abandonment option analysis yields a result of $166.80, indicating that at this price and above, the optimal decision is to sell the asset immediately, given the assumed volatility and the other input parameters. At any lower salvage value, there is option value, and at any higher salvage value, there will be no option value. This break-even salvage point is the *optimal trigger value*. Once the market price of this asset exceeds this value, it is optimal to abandon. Finally, adding a *Dividend Rate*, the *cost of waiting before abandoning the asset* (e.g., the annualized taxes and maintenance fees that have to be paid if you keep the asset and do not sell it off, measured as a percentage of the present value of the asset) will decrease the option value. Hence, the break-even trigger point, where the option becomes worthless, can be calculated by successively choosing higher dividend levels. This break-even point again illustrates the trigger value at which the option should be optimally executed immediately, but this time with respect to a dividend yield. That is, if the *cost of carry* or holding on to the option, or the option's *leakage value* is high, that is, if the *cost of waiting* is too high, don't wait and execute the option immediately.

Other applications of the abandonment option include buyback lease provisions in a contract (guaranteeing a specified asset value); asset preservation flexibility; insurance policies; walking away from a project and selling off its intellectual property; purchase price of an acquisition; and so forth. To illustrate, following are some additional quick examples of the abandonment option and sample exercises.

- An aircraft manufacturer sells its planes of a particular model in the primary market for say $30M each to various airline companies. Airlines are usually risk-averse and may find it hard to justify buying an additional plane with all the uncertainties in the economy, demand, price competition, and fuel costs. When uncertainties become resolved over time, airline carriers may have to reallocate and reroute their existing portfolio of planes globally, and an excess plane on the tarmac is very costly. The airline can sell the excess plane in the secondary market where smaller regional carriers buy used planes, but the price uncertainty is very high and is subject to significant volatility, of say, 45 percent, and may fluctuate wildly between $10M and $25M for this class of aircraft. The aircraft manufacturer can reduce the airline's risk by providing a *buyback provision* or abandonment option, where at anytime within the next five years, the manufacturer agrees to buy back the plane at a guaranteed residual salvage price of $20M, at the request of the airline.

The corresponding risk-free rate for the next five years is 5 percent. This reduces the downside risk of the airline, and hence reduces its risk, chopping off the left tail of the price fluctuation distribution, and shifting the expected value to the right. This abandonment option provides risk reduction and value enhancement to the airline. *Applying the abandonment option in SLS using a 100-step binomial lattice, we find that this option is worth $3.52M. If the airline is the smarter counterparty and calculates this value and gets this buyback provision for free as part of the deal, the aircraft manufacturer has just lost over 10 percent of its aircraft value that it left on the negotiation table. Information and knowledge is highly valuable in this case.*

- A high-tech disk-drive manufacturer is thinking of acquiring a small startup firm with a new micro drive technology (a super-fast and high-capacity pocket hard drive) that may revolutionize the industry. The startup is for sale and its asking price is $50M based on an NPV fair market value analysis some third-party valuation consultants have performed. The manufacturer can either develop the technology themselves or acquire this technology through the purchase of the firm. The question is, how much is this firm worth to the manufacturer, and is $50M a good price? Based on internal analysis by the manufacturer, the NPV of this microdrive is expected to be $45M, with a cash flow volatility of 40 percent, and it would take another three years before the microdrive technology is successful and goes to market. Assume that the three-year risk-free rate is 5 percent. In addition, it would cost the manufacturer $45M in present value to develop this drive internally. If using an NPV analysis, the manufacturer should build it themselves. However, if you include an abandonment option analysis whereby if this specific microdrive does not work, the start-up still has an abundance of intellectual property (patents and proprietary technologies) as well as physical assets (buildings and manufacturing facilities) that can be sold in the market at up to $40M. *The abandonment option together with the NPV yields $51.83, making buying the start-up worth more than developing the technology internally, and making the purchase price of $50M worth it.* (See the section on Expansion Option for more examples on how this start-up's technology can be used as a platform to further develop newer technologies that can be worth a lot more than just the abandonment option.)

Figure 10.1 shows the results of a simple abandonment option with a 10-step lattice as discussed previously, while Figure 10.2 shows the audit sheet that is generated from this analysis.

Figure 10.3 shows the same abandonment option but with a 100-step lattice. To follow along, open the example file by clicking on *Start* | *Programs* | *Real Options Valuation* | *Real Options Super Lattice Solver* | *Sample Files* | *Abandonment American Option*. Notice that the 10-step lattice yields

Option Valuation Audit Sheet

Assumptions		Intermediate Computations	
PV Asset Value ($)	$120.00	Stepping Time (dt)	0.5000
Implementation Cost ($)	$90.00	Up Step Size (up)	1.1934
Maturity (Years)	5.00	Down Step Size (down)	0.8380
Risk-free Rate (%)	5.00%	Risk-neutral Probability	0.5272
Dividends (%)	0.00%		
Volatility (%)	25.00%	**Results**	
Lattice Steps	10	Auditing Lattice Result (10 steps)	$125.48
Option Type	Custom	Super Lattice Result (10 steps)	$125.48

User-Defined Inputs Terminal: Max(Asset, Salvage)
Intermediate: Max(Salvage, @@)

Name	salvage									
Value	90.00									
Starting Step	0									

Underlying Asset Lattice

										702.93
									589.03	
								493.59		493.59
							413.61		413.61	
						346.59		346.59		346.59
					290.43		290.43		290.43	
				243.37		243.37		243.37		243.37
			203.94		203.94		203.94		203.94	
		170.89		170.89		170.89		170.89		170.89
	143.20		143.20		143.20		143.20		143.20	
120.00		120.00		120.00		120.00		120.00		120.00
	100.56		100.56		100.56		100.56		100.56	
		84.26		84.26		84.26		84.26		84.26
			70.61		70.61		70.61		70.61	
				59.17		59.17		59.17		59.17
					49.58		49.58		49.58	
						41.55		41.55		41.55
							34.82		34.82	
								29.17		29.17
									24.45	
										20.49

Option Valuation Lattice

										702.93
									589.03	
								493.59		493.59
							413.61		413.61	
						346.59		346.59		346.59
					290.43		290.43		290.43	
				243.43		243.37		243.37		243.37
			204.30		204.06		203.94		203.94	
		172.07		171.61		171.15		170.89		170.89
	146.01		145.36		144.61		143.77		143.20	
125.48		124.77		123.88		122.77		121.22		120.00
	109.32		108.49		107.41		105.93		103.20	
		97.95		97.13		96.03		94.57		90.00
			91.44		90.88		90.13		90.00	
				90.00		90.00		90.00		90.00
					90.00		90.00		90.00	
						90.00		90.00		90.00
							90.00		90.00	
								90.00		90.00
									90.00	
										90.00

FIGURE 10.2 Audit Sheet for the Abandonment Option

$125.48 while the 100-step lattice yields $125.45, indicating that the lattice results have achieved convergence. The Terminal Node Equation is *Max (Asset,Salvage)* which means the decision at maturity is to decide if the option should be executed, selling the asset and receiving the salvage value, or not to execute, holding on to the asset. The Intermediate Node Equation used is *Max(Salvage,@@)* indicating that before maturity, the decision is either to execute early in this American option to abandon and receive the salvage value, or to hold on to the asset, and hence, hold on to and keeping the

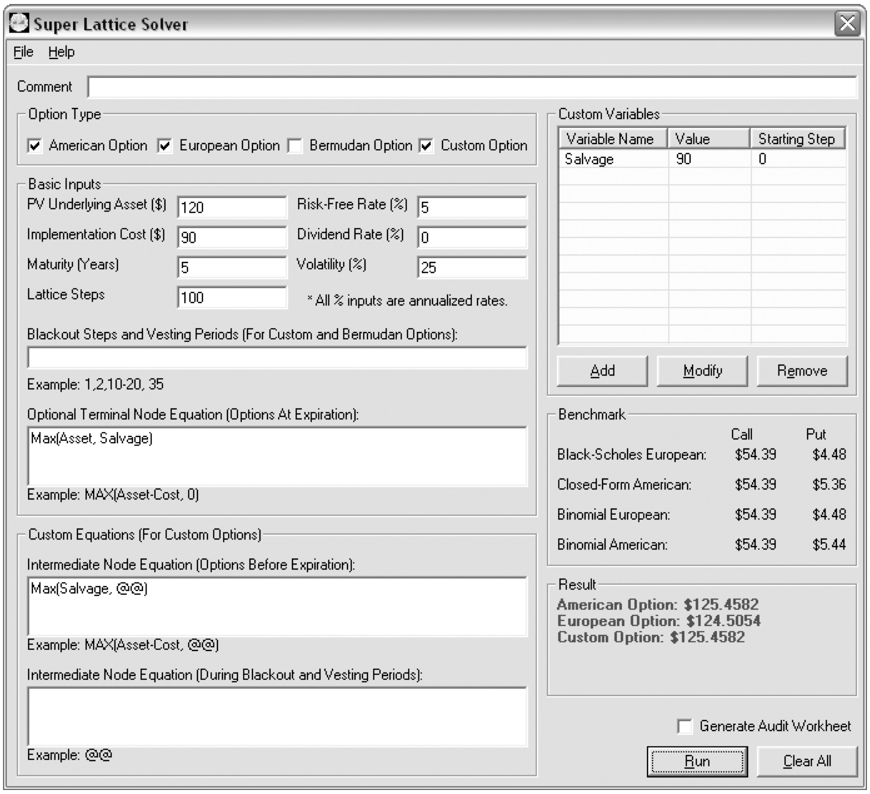

FIGURE 10.3 American Abandonment Option with 100-Step Lattice

option open for potential future execution, denoted simply as @@. Figure 10.4 shows the European version of the abandonment option, where the Intermediate Node Equation is simply @@, as early execution is prohibited before maturity. Of course, being only able to execute the option at maturity is worth less ($124.5054 compared to $125.4582) than being able to exercise earlier. The example files used are: *Abandonment American Option* and *Abandonment European Option*. For example, the airline manufacturer in the previous case example can agree to a buyback provision that can be exercised at any time by the airline customer versus only at a specific date at the end of five years—the former American option will clearly be worth more than the latter European option.

Sometimes, a Bermudan option is appropriate, where there might be a vesting period or blackout period when the option cannot be executed. For instance, if the contract stipulates that for the five-year abandonment buyback contract, the airline customer cannot execute the abandonment option

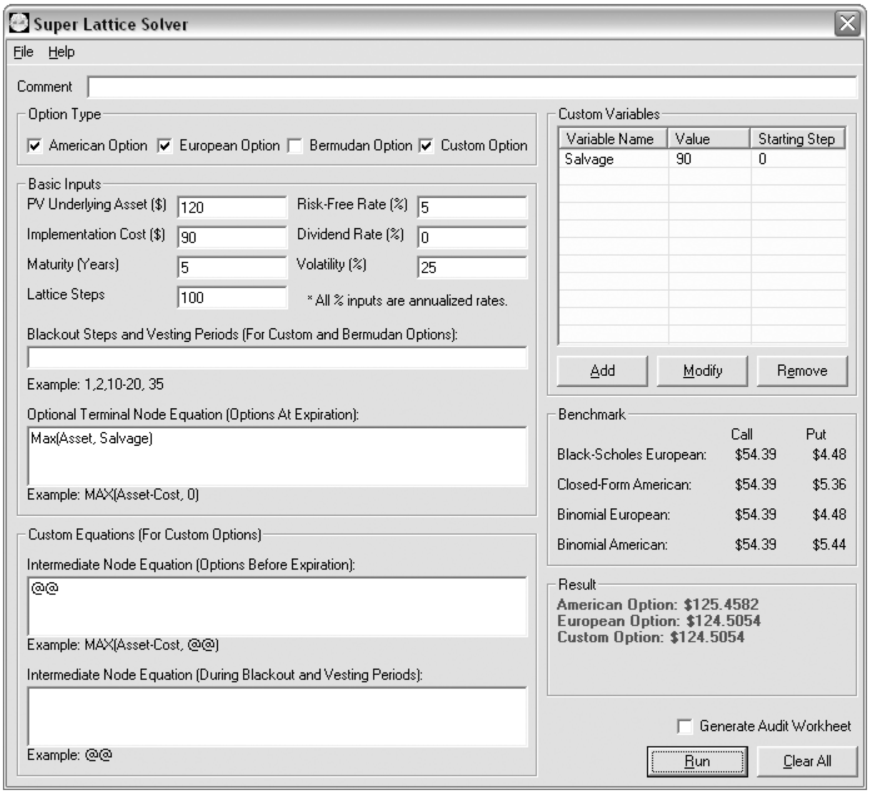

FIGURE 10.4 European Abandonment Option with 100-Step lattice

within the first 2.5 years. This is shown in Figure 10.5 using a Bermudan option with a 100-step lattice on five years, where the blackout steps are from 0 to 50. This means that during the first 50 steps (as well as right now or step 0), the option cannot be executed. This is modeled by inserting @@ into the Intermediate Node Equation (During Blackout and Vesting Periods). This forces the option holder to only keep the option open during the vesting period, preventing execution during this blackout period.

You can see that the American option is worth more than the Bermudan option, which is worth more than the European option in Figure 10.5, by virtue of each option type's ability to execute early and the frequency of execution possibilities.

Sometimes, the salvage value of the abandonment option may change over time. To illustrate, in the previous example of an acquisition of a start-up firm, the intellectual property will most probably increase over time because

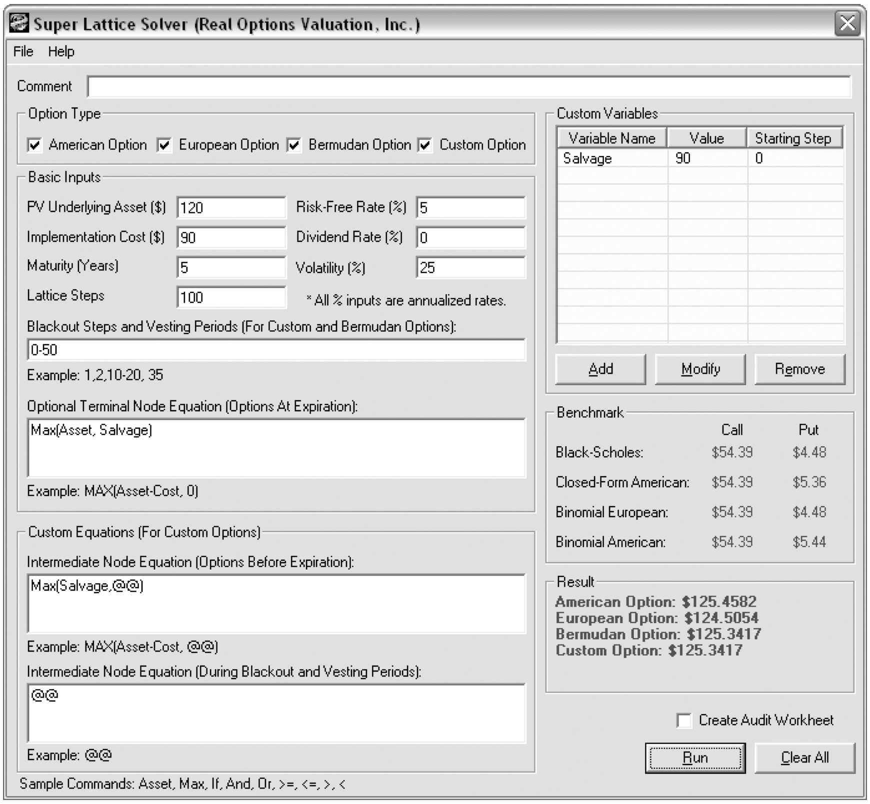

FIGURE 10.5 Bermudan Abandonment Option with 100-Step Lattice

of continued R&D activities, thereby changing the salvage values over time. An example is seen in Figure 10.6, where there are five salvage values over the five-year abandonment option. This can be modeled by using the Custom Variables. Click on *ADD* and input the variables one at a time as seen in Figure 10.6's Custom Variables list. Notice that the same variable name (*Salvage*) is used but the values change over time, and the starting steps represent when these different values become effective. For instance, the salvage value $90 applies at step 0 until the next salvage value of $95 takes over at step 21. This means that for a five-year option with a 100-step lattice, the first year including the current period (steps 0 to 20) will have a salvage value of $90, which then increases to $95 in the second year (steps 21 to 40), and so forth. Notice that as the value of the firm's intellectual property increases over time, the option valuation results also increase, which makes logical sense. You can also model in blackout vesting periods for the first six months (steps 0–10 in

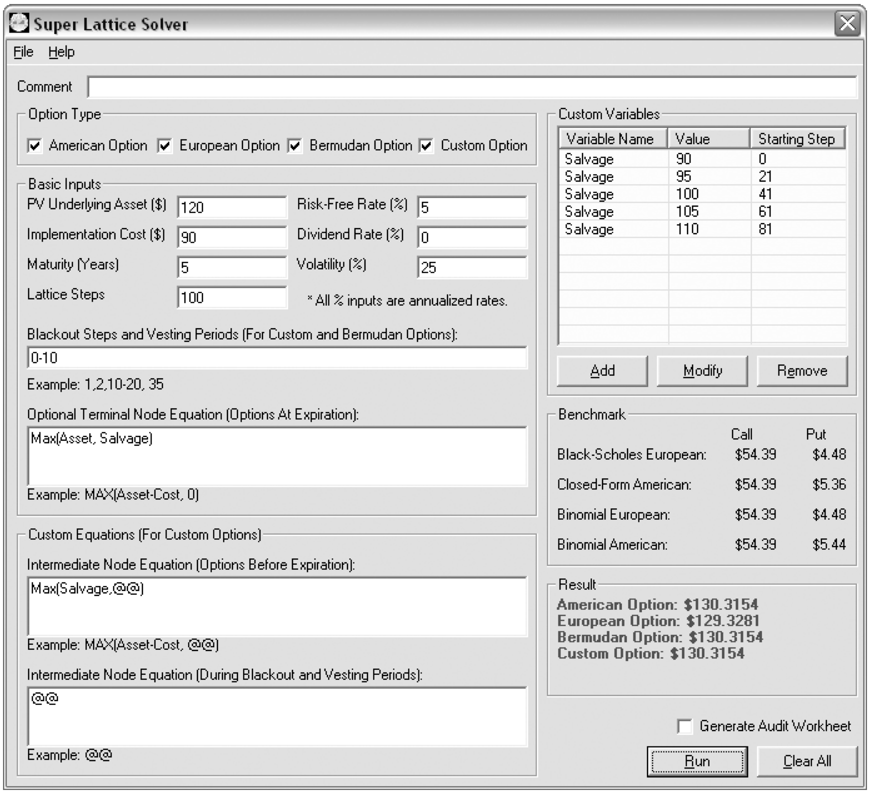

FIGURE 10.6 Customized Abandonment Option

the blackout area). The blackout period is very typical of contractual obligations of abandonment options where during specified periods, the option cannot be executed (a cooling-off period).

Exercise: Option to Abandon

Suppose a pharmaceutical company is developing a particular drug. However, due to the uncertain nature of the drug's development progress, market demand, success in human and animal testing, and FDA approval, management has decided that it will create a strategic abandonment option. That is, at any time period within the next five years of development, management can review the progress of the R&D effort and decide whether to terminate the drug development program. After five years, the firm would have either succeeded or completely failed in its drug development initiative, and there exists no option value after that time period. If the program is terminated, the firm can potentially sell off its intellectual property rights of the drug in question to another pharmaceutical firm with which it has a contractual agreement. This contract with the other firm is exercisable at any time within this time period, at the whim of the firm owning the patents.

Using a traditional DCF model, you find the present value of the expected future cash flows discounted at an appropriate market risk-adjusted discount rate to be $150 million. Using Monte Carlo simulation, you find the implied volatility of the logarithmic returns on future cash flows to be 30 percent. The risk-free rate on a riskless asset for the same time frame is 5 percent, and you understand from the intellectual property officer of the firm that the value of the drug's patent is $100 million contractually, if sold within the next five years. For simplicity, you assume that this $100 million salvage value is fixed for the next five years. You attempt to calculate how much this abandonment option is worth and how much this drug development effort on the whole is worth to the firm. By virtue of having this safety net of being able to abandon drug development, the value of the project is worth more than its net present value. You decide to use a closed-form approximation of an American put option because the option to abandon drug development can be exercised at any time up to and including the expiration date. You also decide to confirm the value of the closed-form analysis with a binomial lattice calculation. With these assumptions, do the following exercises, answering the questions that are posed:

1. Solve the abandonment option problem manually using a 10-step lattice and confirm the results by generating an audit sheet using the SLS software.
2. Select the right choice for each of the following:
   a. Increases in maturity (increase/decrease) an abandonment option value.
   b. Increases in volatility (increase/decrease) an abandonment option value.
   c. Increases in asset value (increase/decrease) an abandonment option value.
   d. Increases in risk-free rate (increase/decrease) an abandonment option value.
   e. Increases in dividend (increase/decrease) an abandonment option value.
   f. Increases in salvage value (increase/decrease) an abandonment option value.
3. Apply 100 steps using the software's binomial lattice.
   a. How different are the results as compared to the five-step lattice?
   b. How close are the closed-form results compared to the 100-step lattice?
4. Apply a 3 percent continuous dividend yield to the 100-step lattice.

a. What happens to the results?
b. Does a dividend yield increase or decrease the value of an abandonment option? Why?

5. Assume that the salvage value increases at a 10 percent annual rate. Show how this can be modeled using the software's *Custom Variables List*.
6. Explain the differences in results when using the *Black-Scholes* and *American Put Option Approximation* in the benchmark section of the Single Asset SLS software.

AMERICAN, EUROPEAN, BERMUDAN, AND CUSTOMIZED CONTRACTION OPTION

A *Contraction Option* evaluates the flexibility value of being able to reduce production output or to contract the scale and scope of a project when conditions are not as amenable, thereby reducing the value of the asset or project by a *Contraction Factor*, but at the same time creating some cost *Savings*. As an example, suppose you work for a large aeronautical manufacturing firm that is unsure of the technological efficacy and market demand for its new fleet of long-range supersonic jets. The firm decides to hedge itself through the use of strategic options, specifically an option to contract 10 percent of its manufacturing facilities at any time within the next five years (i.e., the *Contraction Factor* is 0.9).

Suppose that the firm has a current operating structure whose static valuation of future profitability using a DCF model (in other words, the present value of the expected future cash flows discounted at an appropriate market risk-adjusted discount rate) is found to be $1,000M (*PV Asset*). Using Monte Carlo simulation, you calculate the implied volatility of the logarithmic returns of the asset value of the projected future cash flows to be 30 percent. The risk-free rate on a riskless asset (five-year U.S. Treasury Note with zero coupons) is found to be yielding 5 percent.

Further, suppose the firm has the option to contract 10 percent of its current operations at any time over the next five years, thereby creating an additional $50 million in savings after this contraction. These terms are arranged through a legal contractual agreement with one of its vendors, who had agreed to take up the excess capacity and space of the firm. At the same time, the firm can scale back and lay off part of its existing workforce to obtain this level of savings (in present values).

The results indicate that the strategic value of the project is $1,001.71M (using a 10-step lattice as seen in Figure 10.7), which means that the NPV currently is $1,000M and the additional $1.71M comes from this contraction option. This result is obtained because contracting now yields 90 percent of $1,000M + $50M, or $950M, which is less than staying in business and not