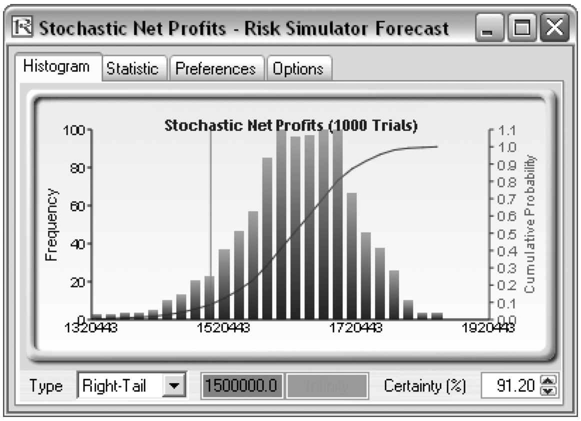

FIGURE 14.23 Sample breakeven points.

In contrast, had optimization and simulation risk analysis not been performed, the results would have been a highly suboptimal set of results. For instance, based on the required minimum and maximum production required in each period, say we manufacture at the average of the forecasted values; the total net profits would have been $13.43 million or manufacturing at the required minimum required values returns $0.71 million in net profits. Therefore, given such huge swings in values, running optimization guarantees the maximum possible net profits of $17.54 million subject to the uncertainties and risks inherent in the demand forecasts.

To conclude, Monte Carlo simulation, forecasting, and optimization are crucial in determining the risk elements and uncertainties of pricing and demand levels. In addition, the analysis provides a set of valid optimal quantities to manufacture given these uncertainty demand levels, all the while considering the risk of the business line. Thus, using risk analysis, decision makers can not only decide which business lines or parts to manufacture, but how much to manufacture, when to manufacture them, and if required, to decide the optimal price points to sell the parts, maximize profits, and minimize any losses and risks.

CASE STUDY: THE BOEING COMPANY'S STRATEGIC ANALYSIS OF THE GLOBAL EARTH OBSERVATION SYSTEM OF SYSTEMS

This case study was written by Ken Cobleigh, Dan Compton, and Bob Wiebe, from The Boeing Company in Seattle, Washington, with assistance from the author. This is an actual consulting project performed by Ken, *Dan, Bob and the author on the GEOSS system. Although the facts are correct at the time of writing, the analysis has been significantly simplified for the purposes of this case study.*

A Background on the Global Earth Observation System of Systems

On February 16, 2005, 61 countries agreed to a plan that, over the next 10 years, humanity will revolutionize its understanding of the earth and how it works. Agreement for a 10-year implementation plan for a Global Earth Observation System of Systems, known as GEOSS, was reached by member countries of the Group on Earth Observations at the Third Observation Summit held in Brussels. Nearly 40 international organizations also support the emerging global network. The number of participating countries has nearly doubled, and interest has accelerated since the December 2004 tsunami devastated parts of Asia and Africa. In the coming months, more countries and global organizations are expected to join the historic initiative. The GEOSS project will help all nations involved produce and manage their information in a way that benefits the environment and humanity by taking the pulse of the planet. The beneficiaries are divided into nine major categories, as depicted in Figure 14.24.

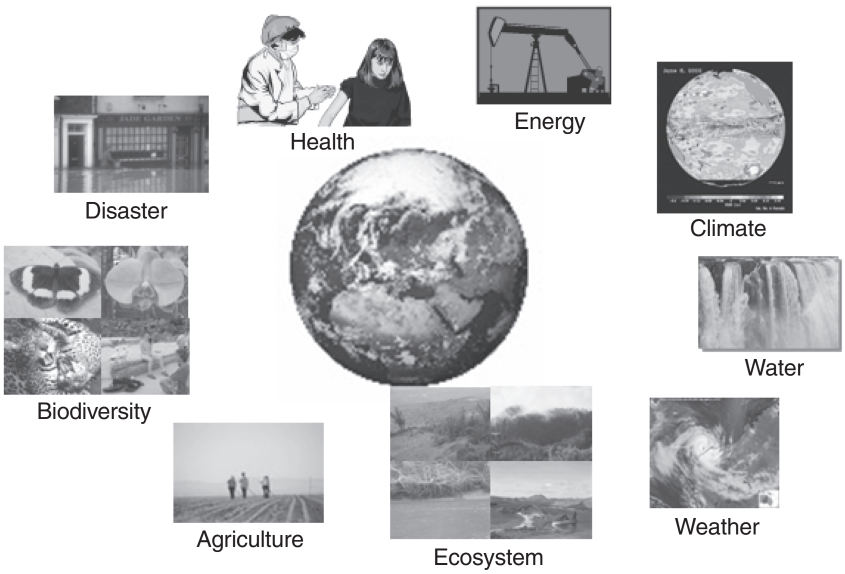

FIGURE 14.24 Societal benefits from earth observations.

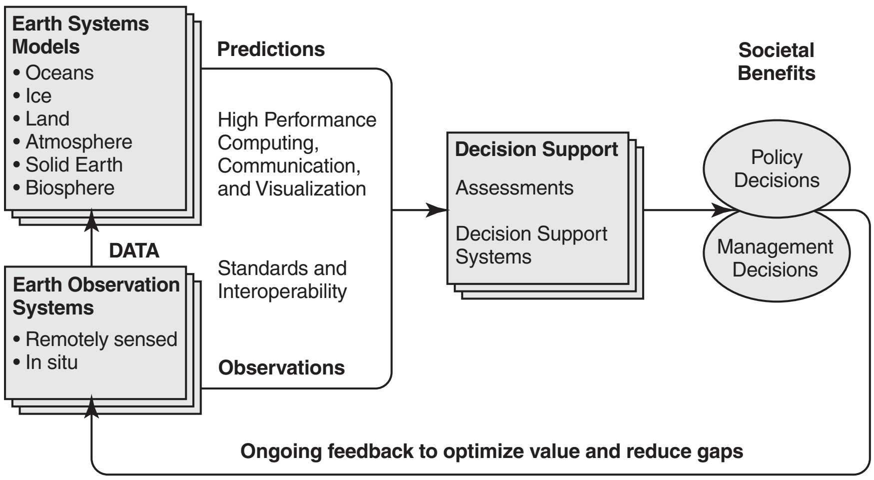

FIGURE 14.25 GEOSS dynamic decision process.

The data can come from satellites, airplanes, balloons, ships, radars, river gauges, ground weather stations, buoys, and field data collected on recorders as well as data collected with pencil and paper. An end-to-end architecture was derived from the basic needs of the system and defined into three groups: the observations systems and other domain data; the GEOSS information architecture; and the user communities. This is shown in Figures 14.25 and 14.26. Some of the applications can be as basic as measuring an ecosystem's biodiversity of animal life to measuring, capturing, analyzing, and better predicting natural disasters like tsunamis, earthquakes, hurricanes, and so forth, providing a global early warning system, saving lives in the process.

Currently, several issues must be overcome in order to allow a long-term high-level vision such as the GEOSS to become a reality. An assessment was made with the technical GEOSS community, which comprised several subcommittees; the one the authors consulted with was the architecture subcommittee. The major issues are summarized in the following list:

- Capability of supporting multiple data formats and exchanging between formats.
- Agree on a new standard format for raw and processed data for new systems.
- Provide information assurance (knowing the data will arrive uncorrupted).
- Provide data, information security, and controlled access (country restrictions, classified data, and so forth).

- Assure easy use of data and information including training, data mining, and other usability tools.
- Enable the creation and use of decision support tools.
- Allow data and knowledge products (higher-level processed products through the use of multiple sensor fusing).
- Assure easy global access.
- Allow data and knowledge products (higher level processed products through the use of multiple sensor and nonsensor fusing).
- Provide high throughput end to end.
- Support nonelectronic transfer of data and information.
- Provide low latency.

As can be seen, many of these high level issues are going to be politically and economically charged. For instance, is the economic benefit decided by the country's gross domestic product or wealth, or by the countries that are in the most need of the benefits? Clearly, a lot of discussions and negotiations need to occur before such a system can be realized. And most likely, it will happen in stages.

One current problem is that many systems are built as stand-alone or stovepipe systems. Their data does not easily register, correlate, or fuse with

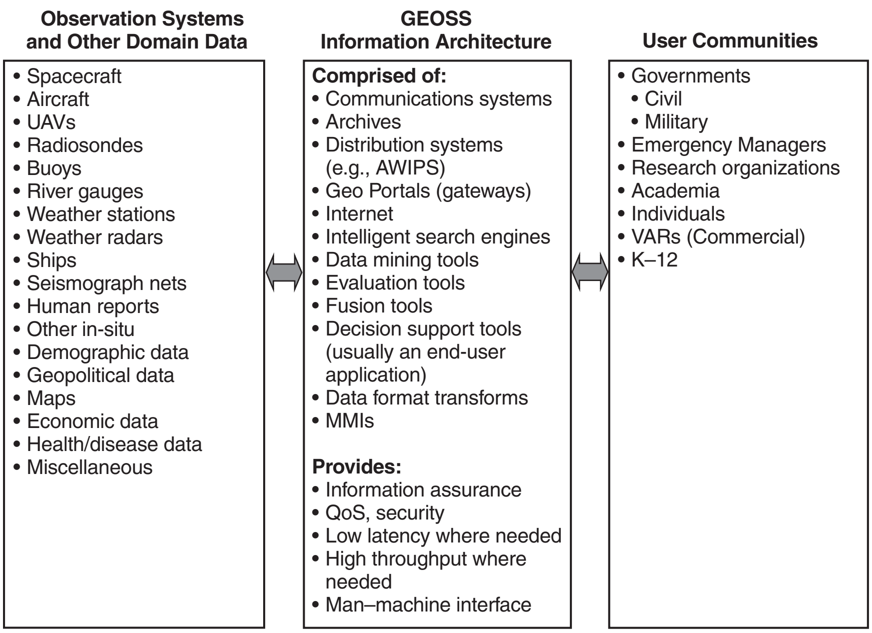

FIGURE 14.26 GEOSS end-to-end architecture.

data from other systems, although in a few cases this is not true, as in some of the National Oceanographic and Atmospheric Administration (NOAA) applications. Another key issue is that many countries simply are not open to sharing their data with the world, even though there are obvious advantages to doing so. They may feel their national security or exclusive economic zones (the 200 nautical mile offshore areas from most countries) are at risk. These issues will need to be resolved before a working implementation can occur. Once these issues are resolved, it is obvious how powerful such a system of systems will be.

A Background on Systems Dynamics

In order to perform a strategic analysis of the GEOSS system, we need to apply Monte Carlo simulation, real options analysis, and couple them with a systems dynamics model. Therefore a quick segue is required here to briefly explain the basics of systems dynamics.

Although systems engineering is a disciplined approach to identifying and specifying requirements as well as architecting systems, systems dynamics allows one to observe the behavior of a system under given circumstances. One such model that makes this possible is the Ventana Vensim model, which allows one to conceptualize, document, simulate, analyze, and optimize models of dynamic systems. Systems dynamics models allow models to be built from causal loops or stocks and flow diagrams. By connecting words with arrows, relationships among system variables are entered and recorded as causal connections. This information is used by the mathematical equations in the model to help form a complete simulation model. The model can be analyzed through the building process, looking at the causes and uses of a variable, and the loops involving the variable. When you have built a model that can be simulated, systems dynamics let you thoroughly explore the behavior of the model.

As a simple example, Figure 14.27 shows the rabbit and fox population behavior and the interaction between the two populations within a systems dynamics model. The model has slider bars built into the birth rates, the initial population, and the average life for the rabbit and fox populations, as well as the fox food requirements and the carrying capacity of the rabbit population. As these bars are adjusted, the remaining variables change the number of births (population and deaths of rabbits and foxes, rabbit crowding, fox consumption of rabbits, and fox food availability). Variables can also be expressed as lookup tables. In this way, we can investigate the behavior of the rabbit and fox population and their interrelationships.

Of course, a model is only as good as its builder and the underlying assumptions. However, systems dynamics have built-in tools that help the builder assess if the model makes sense and the units are correct.

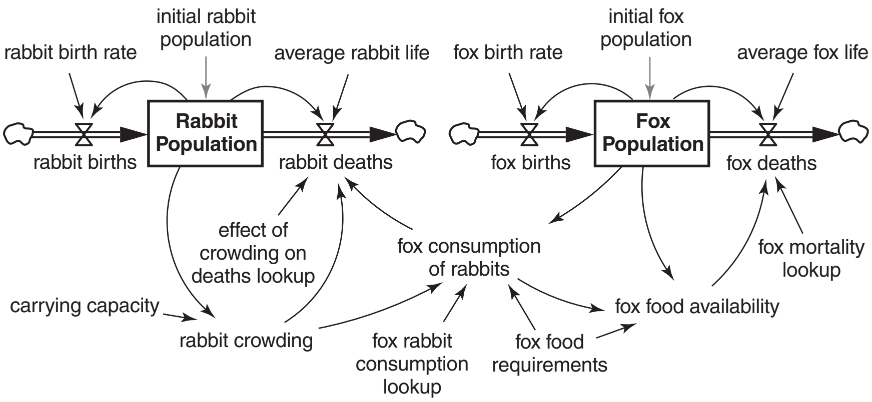

FIGURE 14.27 Sample fox-rabbit population systems dynamics model.

Creation of GEOSS Systems Dynamics Model

Next, the GEOSS model was created using systems dynamics concepts and based on the U.S. military's Office of Force Transformation's model of Network Centric Operations (NCO) as shown in Figure 14.28. The tenets of the NCO model were then modeled. When presented to the GEOSS experts, it was noticed that the tenets of NCO could be slightly modified to fit the GEOSS model, as shown in Figure 14.29.

- A robustly networked force improves information sharing.
- Information sharing and collaboration enhance the quality of information and shared situational awareness.
- Shared situational awareness enables collaboration and self-synchronization, and enhances sustainability and speed of command.
- These in turn dramatically increase mission effectiveness.

Top Level Measures for Exploring NCO Hypothesis

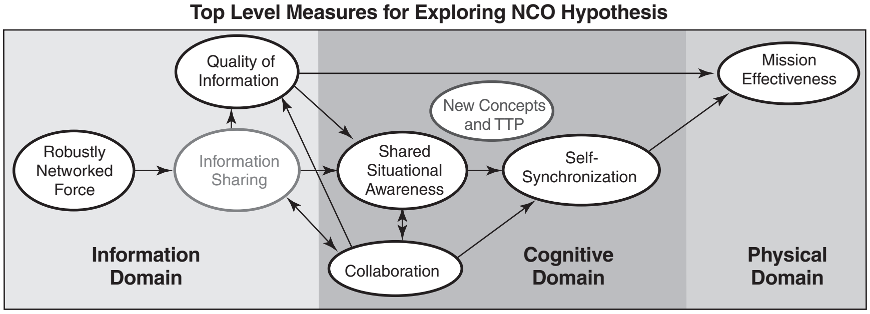

FIGURE 14.28 The Office of Force Transformation NCO model tenets.

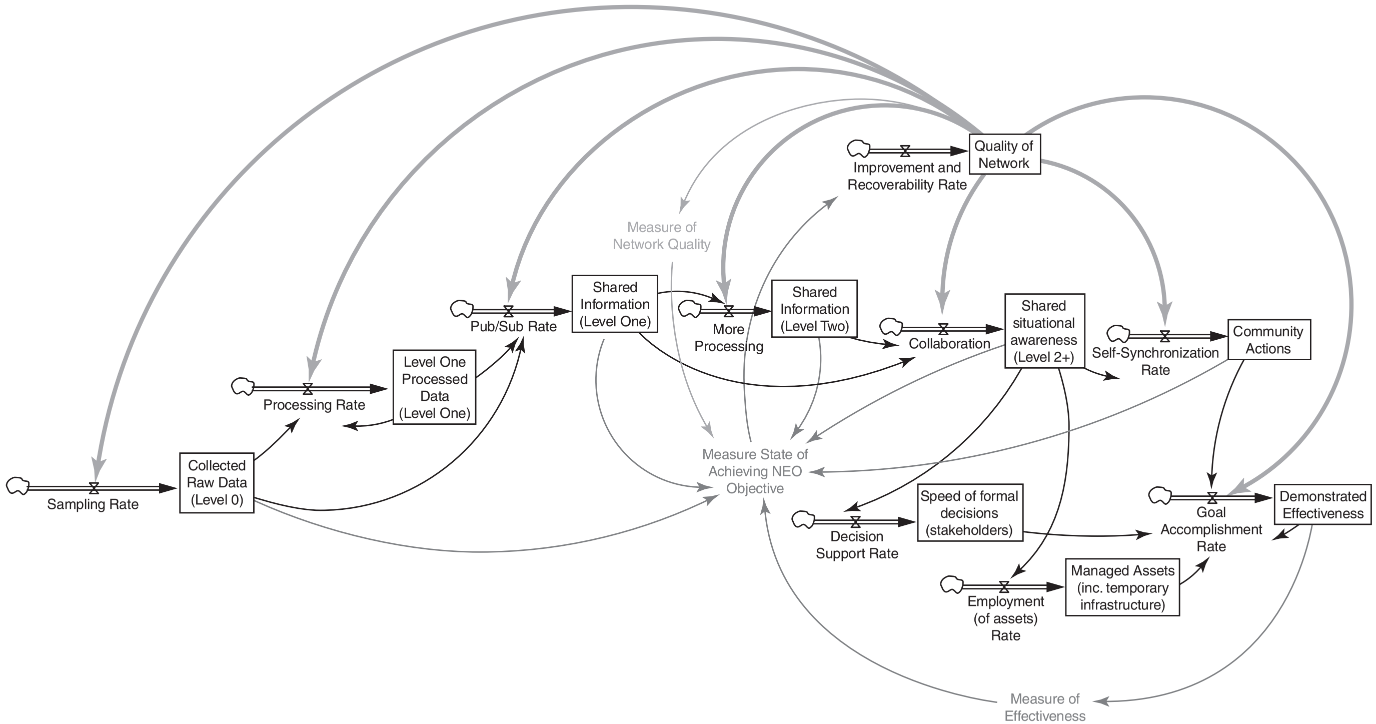

FIGURE 14.29 Systems dynamics model of GEOSS.

Seventy-four technology areas were defined to be required for this large-scale System of Systems (SoS) architecture to operate. An optimization run was then done to determine the most influential technologies in determining system effectiveness, which is largely driven by collaboration. Next, the link to real options analysis was accomplished so the relative value of each technology area could be assessed.

Real Options Valuation Integration and Cost–Benefit Results

The social and economic benefits of a fully developed GEOSS system are very substantial. For instance, according to the U.S. Environmental Protection Agency (EPA), the following is only a small list of the potential benefits:

- We could more accurately know the severity of next winter's weather, with strong implications for emergency managers, transportation, energy and medical personnel, farmers, families, manufacturers, store owners, and others. Weather- and climate-sensitive industries account for one-third of the nation's gross domestic product (GDP), or $3 trillion.
- We could forecast weather one degree Fahrenheit more accurately, saving at least $1 billion annually in U.S. electricity costs.
- With coastal storms reflecting 71 percent, or $7 billion, of U.S. disaster losses every year, improved forecasting would have a major favorable impact on preparedness.
- In the United States, at a cost of $4 billion annually, weather is responsible for about two-thirds of aviation delays—$1.7 billion of which would be avoidable with better observations and forecasts.
- Benefits from more effective air quality monitoring could provide real-time information as well as accurate forecasts that, days in advance, could enable us to mitigate the effects of poor quality through proper transportation and energy use.
- Benefits from ocean instrumentation that, combined with improved satellite earth-observing coverage, could provide revolutionary world-wide and regional climate forecasts, enabling us, for example, to predict years of drought.
- Benefits from real-time monitoring and forecasting of the water quality in every watershed and accompanying coastal areas could provide agricultural interests with immediate feedback and forecasts of the correct amount of fertilizers and pesticides to apply to maximize crop generation at minimum cost, helping to support both healthy ecosystems and greatly increased U.S. fishery output and value from coastal tourism.
- Globally, an estimated 300 million to 500 million people worldwide are infected with malaria each year and about one million die from this

largely preventable disease. With a linked international system, we could pinpoint where the next outbreak of SARS, or bird flu, or West Nile virus, or malaria is likely to hit.

- Natural hazards such as earthquakes, volcanoes, landslides, floods, wildfires, extreme weather, coastal hazards, sea ice and space weather, plus major pollution events, impose a large burden on society. In the United States, the economic cost of disasters averages tens of billions of dollars per year. Disasters are a major cause of loss of life and property. The ability of GEOSS to predict, monitor, and respond to natural and technological hazards is a key consideration in reducing the impact of disasters.

Currently, thousands of individual pieces of technology are gathering earth observations globally. These individual pieces of technologies are demonstrating their value in estimating crop yields, monitoring water and air quality, and improving airline safety. For instance, according to the EPA, U.S. farmers gain about $15 of value for each $1 spent on weather forecasting. Benefits to U.S. agriculture from altering planting decisions are estimated at more than $250 million. The annual economic return to the United States from NOAA's El Niño ocean-observing and forecast system is between 13 and 26 percent. In the meantime, there are thousands of moored and free-floating data buoys in the world's oceans, thousands of land-based environmental stations, and more than 50 environmental satellites orbiting the globe, all providing millions of data sets, but most of these technologies do not yet talk to each other. Until they do, as in a comprehensive GEOSS system, there will always be blind spots and scientific uncertainty. Scientists really cannot know what is happening on our planet without taking the earth's pulse everywhere it beats, all around the globe. Therefore, the challenge is to connect the scientific dots—to build a system of systems that will yield the science on which sound policy must be built.

Strategic Option Pathways

Due to the nature and scope of the project being a global effort, this case study does not expound on all the numerical analyses involved in the quantification of the strategic real options and risk analysis currently being performed. However, a sample strategic tree used for framing real options analysis is provided next to illustrate some of the potential options that GEOSS has. Of course, the entire universe of strategic option pathways and courses of action are a lot more significant than the simple examples illustrated next. See the author's other books on real options for more details on generating strategy trees, as well as modeling and quantifying the real options values using the SLS software (e.g., see *Real Options Analysis: Tools and Techniques, Second Edition* (Wiley, 2005) by Dr. Johnathan Mun).

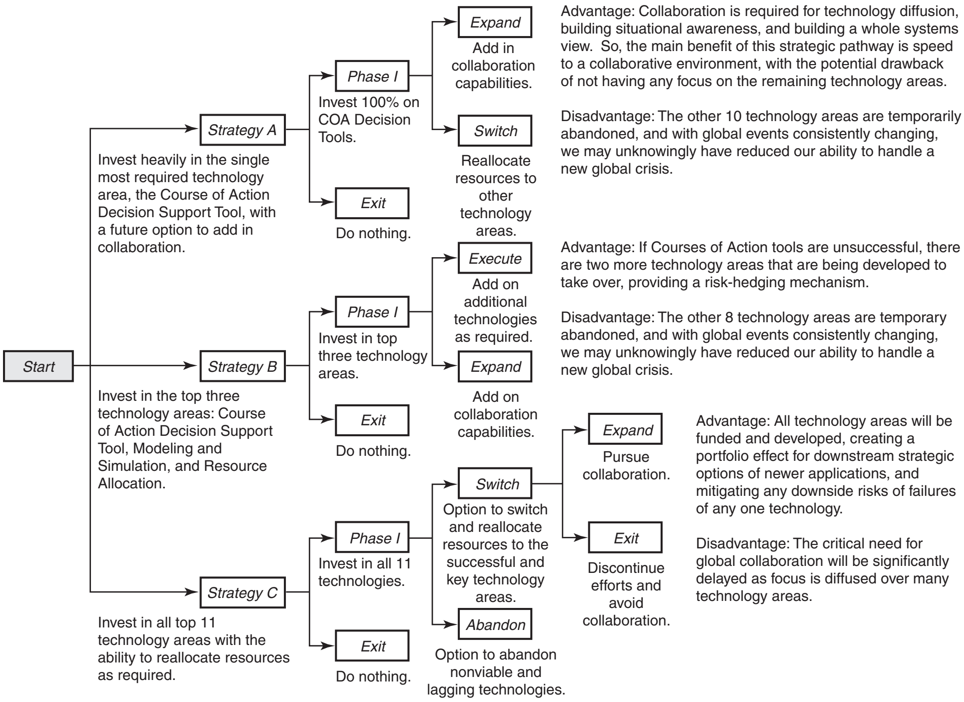

FIGURE 14.30 Sample real options strategies for GEOSS.

To illustrate the basics of the GEOSS options, Figure 14.30 shows three sample pathways of the technology development required as part of a global earth observation system.

Strategy A is to invest heavily in the single most required technology area, the Courses of Action Decision Support tools. It has been determined that Courses of Action technology development builds future options at a faster rate than other technology development because of their influence on collaboration. Collaboration is required for technology diffusion, building situational awareness, and building a whole systems view. The main benefit of this strategic pathway is the speed to a collaborative environment, with the potential drawback of not having any focus on the remaining technology areas.

Strategy B is to invest in the top three technology areas, namely, the Courses of Action Decision Support tools; Modeling and Simulation Decision Support tools; and Resource Allocation tools. One set of technology combinations enables the development of certain follow-on options and activities. So, if Courses of Action tools are unsuccessful, there are two more technology areas that are being developed to take over, providing a risk-hedging mechanism. However, the disadvantage is that the other 8 technology areas are temporarily abandoned, and with global events consistently changing, we may unknowingly have reduced our ability to handle a new global crisis.

Strategy C is to invest in the top 11 technology areas but scale them so that more important technologies get a proportionately higher percentage of the overall investment funding. The advantage is that all technology areas will be funded and developed, creating a portfolio effect for downstream strategic options of newer applications, and mitigating any downside risks of failures of any one technology. However, the disadvantage is that the critical need for global collaboration will be significantly delayed as focus is diffused over many technology areas.

Each of these simple example strategic paths has exit points and each also has an option of whether the technology should be tackled in-house or by some large integrator such as The Boeing Company or by smaller vendors with other expertise in these areas. These are nested options or options within options.

Of course the efforts are ongoing and would pose rather significant analytical and resource challenges. However, with the combinations of simulation, real options, systems dynamics, and optimization tools, the analysis methodology and results can become more valid and robust.

CASE STUDY: VALUING EMPLOYEE STOCK OPTIONS UNDER THE 2004 FAS 123R

This case study is based on Dr. Johnathan Mun's Valuing Employee Stock Options: Under 2004 FAS 123R *(Wiley Finance, 2004). This case study and book applies the same software FASB used to create the valuation examples in FAS 123R's section A87. It was this software application and the training seminars provided by the author for the Board of Directors at FASB, and one-on-one small group trainings for the project managers and research fellows at FASB, that convinced FASB of the pragmatic applications of employee stock options (ESO) valuation. The author consulted for and taught FASB about ESO valuation and is also the creator of the ESO Valuation Toolkit software used by FASB as well as many corporations and consultants.*

Executive Summary

In what the *Wall Street Journal* calls "among the most far-reaching steps that the Financial Accounting Standards Board (FASB) has made in its 30 year history,"[8] in December 2004 FASB released a final revised Statement