Introduction. You are going to participate in an experiment involving technological innovation. The experiment will be conducted over a period of several weeks, during which you will make decisions once per day about research and development of new technologies and implementation and patent protection of technologies you have developed. Your objective is to end up with as much money at the end of the experiment as you can. The end of the experiment will not be announced in advance. Once the experiment is terminated, there will be three "overtime" periods of production so that those who have invested in new technologies in the final periods may realize the benefits of these investments. Performance on the experiment will be judged by how much money you have earned. The class is divided into two groups. Each group will do a separate but similar experiment. There are about six students in each group.

Mode of Interaction. The experiment will consist of a sequence of periods. Each period lasts one day, with Saturday and Sunday combined as one period. Results of the previous period's activities will be distributed as an Excel spreadsheet via email before noon each day. You should respond by entering your decisions for the next period on the spreadsheet and returning it via email no later than 6am the following day. The spreadsheet will be named Name_AB_nn.xls, where Name is your last name, AB is either A or B depending on whether you are part of experiment A or B and nn is the number of the period. For example, if the instructor were participating in experiment A, then his first spreadsheet would be titled Parker_A_01.xls. You should fill in your decisions in the white cells on the **Decision** page of the spreadsheet and save it and return it by email with the same name. ***Do not change anything on any page of the spreadsheet pages except the Decision page.*** All of the rest will be updated for you each day.

Industry. Each of you is a producer in a fairly competitive widget industry. The output of the widget industry is homogeneous, so all producers' widgets sell at the same price in any period. The price is determined by producers' costs. There are significant barriers that prevent new firms from entering the widget market. Most firms in the industry are likely to make profits, at least initially. Those who lower costs quickly may make large profits. Firms with the highest costs may make operating losses. If your firm's cash balance becomes negative or has no possibility of producing profitably or doing research, it leaves the market and you leave the experiment. The market demand for widgets is fairly inelastic. All widget producers in the industry sell the same quantity in any given period, which depends on the market price and the number of remaining producers. Widget production within a plant is characterized by constant average costs, so cost per unit does not depend on the level of production.

Costs. The cost of widget production consists of two parts: operating costs and materials costs. Operating costs depend on the technology that you use for production as well as how proficient you have become at using that technology. Each technology has a base cost, but your costs will fall for the first two periods that you use a new technology as you progress down the learning curve. As discussed below, there are five different materials that can be used in widget production. Over time, the cost of each material will

change depending on world supply and demand, so even a technology with low operating costs may become less desirable if the price of the material it uses were to rise.

Technology. There are six technological "dimensions" over which one can vary widget-production technology. Your factory can produce widgets at different *speeds*, at different *temperatures*, with different raw *material inputs*, with the input in different *form*, with different *catalysts*, and in processing vessels of different *shapes*. The choices for each of these dimensions are given in the table below:

Speed	Temperature	Material Input	Input Form	Catalyst	Vessel Shape
Very Slow	Frigid	Smithium	Fine Powder	None	Spherical
Slow	Cool	Ricardium	Coarse Powder	Reedium Lutzite	Cylindrical
Moderate	Medium	Malthusium	Granules	Vollium Eliate	Conical
Quick	Warm	Keynesium	Slurry		Cubic
Fastest	Hot	Schumpeterium			Oval
	Sizzling				Pyramidal

Each alternative characteristic in each dimension may contribute positively or negatively to the cost of widget production. There are 10,800 different technologies that can be formed as combinations of the six dimensions of characteristics. Each of the 10,800 has a cost of production associated with it. Each characteristic tends to have a consistent contribution to raising or lowering cost. There is also a unique, idiosyncratic element of cost as well, so some *combinations* of characteristics work better than others. (In other words, if fastest generally has low cost with other temperatures and hot generally has low cost at other speeds, then it is likely, but not certain, that fastest and hot will have low cost.)

Your Plant. You have one plant for making widgets. The initial technology of each player's plant is the same: slow speed, medium temperature, using smithium in fine powder form with no catalyst in a cylindrical vessel. The operating cost of production for this technology is $700 per widget and all learning-curve economies have already occurred, so this cost will not fall with further production. The initial cost of smithium is $200 per widget, making the total production cost $900. Your plant will continue to produce using this technology until you install a new technology in the plant. In order to install a new technology, you must first "learn" it through R&D (see below). Installation of a new technology in your plant may be costly, depending on which dimensions of technology are being changed from those of your current plant. The table below shows the cost of installing new technologies:

Dimension changed	Speed	Temperature	Material Input	Input Form	Catalyst	Vessel Shape
Cost of installation	None	None	$100,000 for new supply network	$50,000 for new input feeding equipment	None	$150,000 for plant modifications
Public informed?	No	No	Yes	No	No	Yes

These costs are cumulative, so if you install a new technology that has both a new kind of material input *and* a new vessel shape relative to the previously installed technology, you incur $250,000 of installation

cost. Installation of a known technology can be done immediately. If you install a new technology during a particular period, your production for that period will use the new technology.

Installation of some kinds of new technologies is visible to your competitors. Because processing vessels are very large, the media will report the installation of a new vessel shape in your plant. Similarly, the process of contracting for new material inputs allows information about changes in material inputs to leak out. Other aspects of new technologies will not be known to your competitors.

Learning Curves. There is a certain amount of learning by doing in widget production. The cost figures that your R&D lab reports for a new technology are the *initial* operating cost; as you gain experience with the new technology, operating costs will fall. You can expect costs to fall by about 5% by the third period of production.

Labs. In order to learn new technologies you must undertake research and development, which is done by labs. Labs have three kinds of costs: construction cost, research cost, and decommissioning cost. Constructing a new lab costs $100,000 and requires one period. If you decide to construct a new lab in period six, you will be charged $100,000 in period six and your lab will be ready to begin performing R&D in period seven. Performing R&D in a lab once it is constructed costs $80,000 per period. If you let a lab sit idle, it costs $20,000 per period (just to keep it from decaying and to pay unemployment compensation to your scientists). If you decide to decommission a lab, it costs $20,000 to clean up the site and for severance pay to your scientists. Each player begins with one installed lab.

Research and Development. You can learn new technologies by performing research and development. Once you do the R&D necessary to learn a technology, you will be told its operating cost value and that technology will be available for installation (if consistent with patent restrictions). However, except for technologies that you find out about through patents or espionage, ***you can only learn technologies that are "closely related" to technologies that you already know***. Two technologies are closely related if they differ in *only one dimension*. For example, you could assign a lab to learn a new technology that has a different temperature (but the same characteristics in other dimensions) as one you already know, or you could learn one that has a different speed, but you could not learn one that has a different temperature *and* a different speed than the closest known technology.

Each R&D project requires the efforts of one lab for at least one period. In many cases, a new technology can be learned in a single period, but sometimes it takes longer. You rarely know for sure how long a given technology will take to research until you do it. The table below shows the expected time required for R&D, according to which dimension is being changed from a known technology:

Dimension changed	Speed	Temperature	Material Input	Input Form	Catalyst	Vessel Shape
Average number of periods required	1.1	1.1	2.0	1.0	1.5	1.8
Range of possible time lags	1 to 2	1 to 2	1 to 3	1	1 to 2	1 to 2

You may notice from the above table that some dimensions (such as material input and vessel shape) seem to cost more (take longer) to research than others. In general, those dimensions that have higher costs also have higher potential payoffs. In other words, it costs a lot to learn to use different materials inputs because you are likely to have to use a lab for two or three years, but using different materials will tend to have a relatively large effect on cost compared with, say, using a different speed or temperature.

Patents. If you learn a new technology, you may be able to patent it. You must patent a technology in the same period that you install it in your plant (or before). Technologies that are already in use by you or anyone else are not eligible for patents (they are no longer novel). There is no monetary cost of patenting. If you patent a process, you have an exclusive right to use or license that process for *seven* periods, including the period in which the patent is requested. The experiment monitor will enforce the patent for you and prevent anyone else from installing it without a license. Once the seven-period life of the patent expires, the technology is in the public domain and can be freely used by all.

When you patent a technology, the cost characteristics of that technology are made public to everyone in the experiment. With the information in the patent, other players can learn the patented technology in one period using one lab, *regardless of whether they already know a closely related technology*. (Although they can learn it, they still cannot install the technology without a license as long as your patent is in force.)

Licensing. If you own a patent, you may with elect to license the patent to other producers for a one-time fee that you set. A producer who purchases a license to a patent may use the patented technology indefinitely, but must still perform the required one period of R&D to learn the technology before it can be installed. If another producer purchases a license to your patent, you will be informed, but the information will not be made public. You may choose not to sell licenses to your patented technologies and may change your mind or change the license price during the life of your patent. However, even if you decide to stop offering licenses, those with previously purchased licenses will still be able to use the technology indefinitely.

Corporate espionage. During any period, you may choose to hire a corporate spy, who will attempt to infiltrate the R&D department of one of your competitors. Hiring a spy costs $100,000 per period. It takes the spy two periods to become sufficiently familiar with the company to obtain the information that you desire. During each of the two periods that the spy is at work, there is a 30% chance (or higher, depending on security) that the spy will be caught. If the spy survives two periods without detection, she will bring you a copy of the competitor's current data spreadsheet, including the details of all known technologies and the competitor's financial history. If she is caught in either period, you get no information, all competitors will be informed of your attempt at espionage, and you will be fined $250,000. After two periods of successful espionage, you may either leave the spy in place or withdraw her. If she remains in place, the same $100,000 per period cost and the same 30% per period probability of detection exist in subsequent periods. But until she is detected the spy will continue to give you updated information about the competitor's spreadsheet. Any player who is convicted of espionage twice

will be put in prison for the rest of the experiment and either another player will take over his or her firm or the firm will be dissolved.

Once you have "learned about" a technology through espionage, you may "learn" the technology in one period by devoting one lab to the project for one period—the same as you may learn a technology that you learn about through a competitor's patent application.

Corporate security. If you are worried about espionage by your rivals, you may hire additional corporate security to try to catch spies. The default security level is Green. By spending more for security, you can raise the level to Amber, Orange, or Red. The following costs and detection probabilities apply:

Level	Cost	Detection Probability
Green	$0	0.3
Amber	$100,000	0.4
Orange	$200,000	0.5
Red	$300,000	0.6

Expenditures on security are *not* public information.

Interest. Any money leftover at the end of a period will earn 5% interest before the beginning of the next period. There is, however, no provision for borrowing, so make sure that you monitor your cash balance carefully.

Accounting and reporting. Each period you will receive an updated spreadsheet that includes a summary of your financial status, the cost characteristics of all technologies known to you, information on all patents that have been granted to you and your rivals, your current installed plant technology and its cost, and the status of all of your R&D labs and the projects on which they are working.

Group profit reporting. Every few periods, the experiment monitor will issue a profit report, revealing to all players the accumulated profits of each player.

Summary of experiment procedure. Each morning except Sundays, you will receive an Excel spreadsheet via email. The front page of this spreadsheet will contain a box at the top with a summary of your current situation: the technology currently installed in your plant, a list of the technologies that you know, your current operating and materials costs of production, the market price of widgets, your current output, revenue and profit figures, the current prices of all materials, and your current cash balance. It will also report on the status or outcome of the R&D projects that each of your labs undertook in the previous period(s) and any industry-wide news such as new patents issued or visible installations of new plants.

The second page of the spreadsheet will be a form on which you can fill in your decisions for the period. You make six kinds of decisions each period.

- You may choose to install a new technology in your plant. To do this, you must already know the technology that you are installing. If it is patented by another player you must own or purchase a license to use it. You must have enough cash to pay any installation and licensing costs.
- You may choose to construct a new lab or decommission an existing one.
- You may choose to use your existing lab(s) to perform R&D projects to learn a new technology. The new technology must either be patented by someone else (or discovered through espionage) or must be closely related to one you already know. You must have enough cash to operate the lab performing the R&D.
- You may choose to take out a patent on a technology that you know, but have not previously installed in your plant. You may not patent a technology that someone else has already patented or installed. You may also set a licensing fee (or refuse to license) for each patent that is currently in force.
- You may license a patent owned by someone else at the price established in the previous period.
- You may choose to engage in corporate espionage or to increase corporate security. To do this, you must have sufficient cash to pay the spy or the security guards for the period.

After filling in these decisions, you should attach the spreadsheet to an email reply in order to submit your decisions. If the experiment monitor receives no decision from you before the deadline (6am), then he will assume that you have taken no action during the period on installing technology, R&D, patenting, or espionage. Any ongoing research projects will be continued, provided you have sufficient cash to pay for them. If there is no ongoing research, your labs will sit idle for the period (costing you $20,000 each).

Ambiguous or erroneous forms. Once in a while, players will make mistakes, for example, asking a lab to research a technology that is not closely related to one they know or asking them to research one that they already know. In such cases, the scientists in the lab will make a random decision about which possible technology to research. (Scientists are like that.) If you discover an error after sending in your spreadsheet, just send another one with a note asking that this one replace the earlier submission. (Make sure that the corrected one arrives before the deadline.)

Once in a while, the experiment monitor makes a mistake! If you see something in your spreadsheet that seems improbable or if some part has not been updated, it is entirely possible that it is wrong. Send a note explaining the anomaly and I'll get back to you as quickly as possible.