"By Prescription Only": A Computer Simulation Game for Understanding the Emergence of New Medical Treatments

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ABSTRACT

This paper presents a computerized system dynamics game in which the player makes "annual" decisions controlling the availability and evaluation of a new medical product with uncertain potential and possible (though initially undetected) side effects. The game has been implemented using the popular spreadsheet program Lotus 1-2-3. This program has on-screen display capabilities allowing for the construction of a user-friendly game that requires no knowledge of system dynamics. A detailed discussion of game mechanics is followed by a description of a classroom experience which led to further development of the original version of the game and some general insights about game-building.

INTRODUCTION

Simulation gaming can be an extremely effective way to stimulate new ideas and insights about a system and to allow for the controlled testing and comparison of alternative policies. Its use is widespread in the military and in business, but games are rarely used for studying public policy questions (Quade 1982, p.194). This is unfortunate, as gaming offers decision-makers (or their representatives) the direct opportunity to test and modify various strategies without the paternal guidance of "outsiders" in that process. The benefits of such "hands-on" participation should not be underestimated: The difficulty of gaining acceptance of solutions formulated largely or exclusively by outside consultants is well-known (Quade 1982, p.199).

Gaming may be used to investigate any system in which there are at least two separate decision-making centers (Bowen 1978; Quade 1982, p.202). A game may either be fully manual or computer-assisted. An example of the former is the "Beer Distribution Game" (Sterman 1984) played in many introductory System Dynamics courses. Teams consisting of four players each compete with each other to see which can best control an inherently unstable production-distribution system. The game is highly stimulating, as attested to by the almost always lively discussion that follows. The important lessons of the game are surely learned more viscerally through active participation than through listening to lectures on the subject.

The Beer Distribution Game is productive not only intellectually, but socially as well. Like many games, it gives people from diverse backgrounds the opportunity to interact as equals, on common ground, in an informal yet directed way. In an organizational setting, this may be one of the few ways to bring people together from different agencies or divisions and get them to see and feel beyond their own narrow territory (Quade 1982, p.201).

Although computer games do not often offer the social benefits of manual games, they do provide substantial advantages in the way of speed, control, bookkeeping, and display of results (Geisler and Ginsburg 1965; Quade 1982, p.197). Speed is of particular importance, because a game that can be played quickly can be played repeatedly. Only through repeated play can the player systematically test the impact of a variety of alternative strategies and, if the program is flexible, test these impacts under a variety of possible contingencies. For example, "Gaming DYNAMO" enables one to test system dynamics models in this way (Pugh 1976, pp.59-66).

It must be said, however, that Gaming DYNAMO is of limited use for decision-makers who have no working knowledge of system dynamics but could benefit from playing a game dealing with their particular problems. Unfortunately, these are the very folks who could benefit most from testing system dynamics models in a game mode, rather than in the fully-automated mode with which system dynamicists themselves are comfortable (and in which they can do their analyses much more rapidly). What is needed, in other words, are dynamic computer games that are "user-friendly" enough to allow for immediate play by people who know no system dynamics, without the need for technical assistance. The purpose of this paper is to present one such game (developed by the author) and discuss its implications.

GAME OVERVIEW

The game in question is "By Prescription Only", which puts the player in the role of "Medical Czar", whose job is to control the availability and evaluation of a new medical product used by physicians to treat some subset of their patients. The new treatment is assumed to have passed initial laboratory testing and been declared ready for clinical use. However, its appropriate clinical use is uncertain and further improvement of the product may be possible.

An overview of the simulation model underlying "By Prescription Only" is presented in Figure 1. This model, consisting of about eighty variables (including thirty levels) and about thirty constants and table functions, is essentially a streamlined version of a larger model presented in Homer (1983) (see also Homer 1981). But unlike the larger model, the number of physicians using the product and the rate at which patients are formally evaluated are determined (within defined limits) by the player once every simulated year, rather than by the computer at every computation interval.

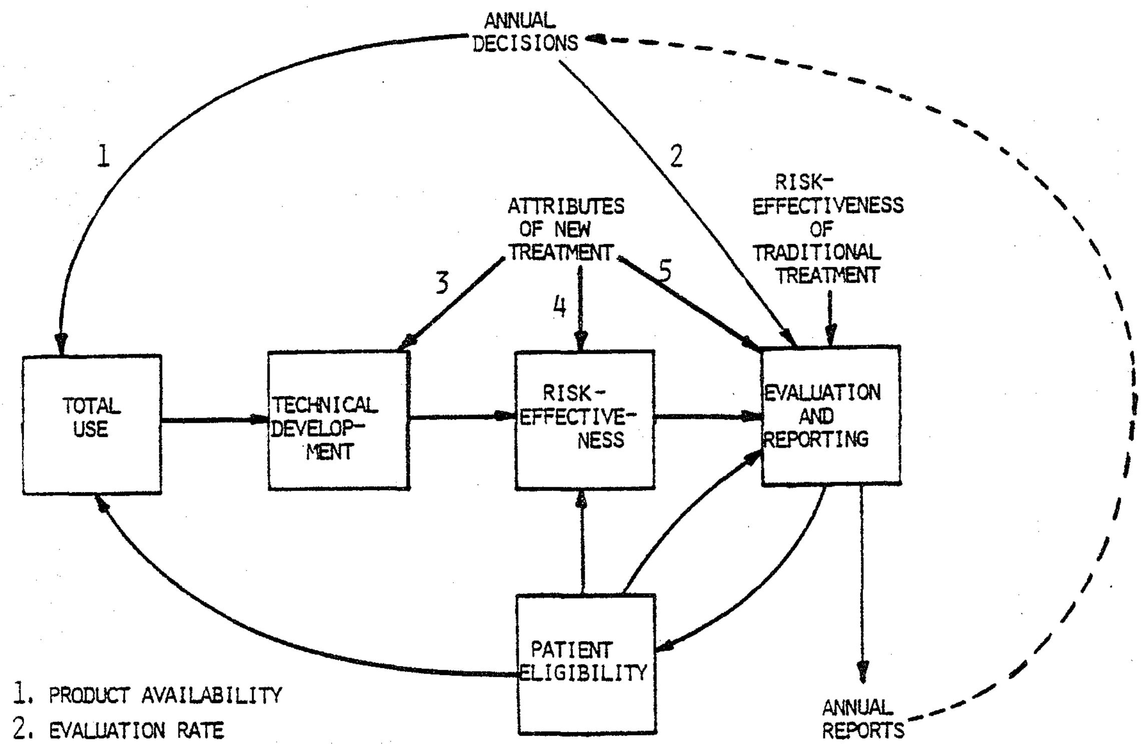

Figure 1 : Overview of the Game's Simulation Model

These two annual player decisions are made on the basis of annual evaluation reports generated by the computer. During each year of simulation, the computer makes periodic decisions regarding patient eligibility (a decision made in real life by physicians) and technical development activity (a decision generally made by the manufacturer), as in the original model. The computer also keeps track of the product's use and improvement, actual versus evaluated outcomes (health benefits and risks), and the number and content of evaluations in the publication pipeline, as in the original model.

Figure 1 indicates how the specific attributes of the new treatment can affect its emergence. A product with low potential for effective use and long-term side effects will have a different pattern of emergence than will a product with greater potential and negligible side effects, for example. A strategy of play that is successful in guiding the smooth emergence of a treatment with one set of attributes may not be as successful in dealing with another sort of treatment (Homer 1981, 1983). Therefore, it is important that the player have the opportunity to test alternative strategies against a variety of possible treatments.

This contingency or sensitivity testing capability is an important feature built into "By Prescription Only" in the form of twenty-four different pre-established treatments that may be selected for play, either by the player or by the computer. The player need know nothing of parameter values and their specific meanings; a new treatment may be selected for play simply by referring to its identifying number (an integer between 1 and 24).

ELEMENTS OF A SPREADSHEET SIMULATION GAME

"By Prescription Only" was implemented using the popular spreadsheet program Lotus 1-2-3, which had sold over a half million copies as of February 1985 and may achieve the select one million unit milestone by the end of the year (Carroll 1985). In its current form (designed on a 256 K RAM DEC Rainbow), the game is stored in two separate "worksheet" files, the first of which introduces the game and permits the selection of a new treatment, while the second directs game play and permits graphing of results. Together, these files require roughly 100 K bytes of disk memory.

The distinct advantage of a spreadsheet program such as Lotus over other programming languages is its on-screen display capability, which allows one to skip from one full-screen display to another complete display immediately after issuing the command to do so. Similarly, a complete, labeled graph of one's choosing can be produced and displayed immediately upon command. Lotus also allows one to construct annotated selection menus which appear in the upper left hand corner of the screen when called up by the appropriate macro (subroutine). In general, any set of commands that can be executed sequentially by Lotus can be automated in the form of a macro.

When the "By Prescription Only" game selection file is retrieved, a macro causes the three screens of introductory material shown in Figure 2 to be displayed, one screen at a time. The game selection menu (not shown in Figure 2) allows the player to specify who will make the selection ("Czar" or "Lotus"). If "Czar" is chosen, then the player is prompted to enter a game number between 1 and 24; this entry is then acknowledged, as shown at the top of Figure 3. Once the game number has been selected, Lotus (behind the scenes, unbeknownst to the player) locates the vector of seven parameters uniquely associated with that game number, and stores this selected vector at a specific location in the worksheet. Five of the seven game parameters define characteristics of the treatment, a sixth specifies the length of game play (ten or fifteen years), and the seventh is the game number itself.

Hello and welcome to "By Prescription Only", the game in which you govern the use and evaluation of a new medical treatment through your authority as this country's "Medical Czar". Good luck!

There are 24 different possibilities for the new treatment. They differ according to the following five factors:

(1) ultimate potential for effective use,
(2) initial technical maturity,
(3) severity of side effects,
(4) frequency of side effects, and
(5) latency time for side effects.

---------------------<press Return to continue>------------------

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The particular treatment you attempt to control (that is, the particular "game" you play) may be selected either by you (Czar) or by the computer (Lotus). If Lotus does the selecting, each of the 24 games has an equal chance of being selected.

In the game, as in real life, the truth surrounding a new medical treatment may be unclear for many years. Your challenge is to deal with that uncertainty by devising a strategy that will work satisfactorily regardless of which treatment is selected.

---------------------<press Return to continue>------------------

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To get started, you will select from the menu in the upper left corner of the screen. Who will choose the game to be played, Lotus (computer) or the Czar (you)?

Make this selection by pointing (use left and right arrow keys as needed), then entering the selection and pressing Return.

Figure 2: Introductory Screen Displays

```
You have selected game number  20
Press RETURN to continue.
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```
Lotus is now getting set for you to play
the game that was just selected.
You will soon receive the first set of
reports on the new treatment and will be
asked to make your first year's decisions
as Medical Czar.
```

```
--------------------------------------------------------------------------
          At start of year:                                  1

R         Recipients reported over the past year:            6   cases

E         Time allowed for observation of outcomes:       0.25   years

P         Fraction of patient population considered
          eligible to receive the new treatment:         10.0%
O
          Reported risk-effectiveness of new
R         treatment relative to standard treatment
          (>=1: acceptable, <1: unacceptable):            2.72
T
          Relative uncertainty as to what are
S         appropriate eligibility criteria (0-1):         100%

          Limit on evaluations for current year:          4625   cases
------------------------<press RETURN to continue>------------------------
```

Figure 3: Selection and Set-Up Message and Annual Reports Displays

Lotus is now instructed to save the game selection worksheet and retrieve the game play worksheet. The latter worksheet is then initialized while the message shown in the middle of Figure 3 is displayed. Initialization involves: (1) copying the game selection vector into the game play worksheet from the game selection worksheet, (2) erasing the output range (which tracks a number of variables for the length of the game for possible graphing later) from the last game that was played, (3) copying the new game's initial output values into the output range's "year 0" sub-range, (4) identifying the best final score to date for the specific treatment that has been selected (a list of "best scores" is stored in the worksheet), (5) simulating the first year of activity, based on initial values, and (6) copying the year-end output values into the "year 1" output range.

The game play worksheet includes an array of entries that allows simulation to be performed in two simple steps. This array contains one row for every model variable and enough columns to account for every computation interval between year-start and year-end; this works out to (1 + 1/DT) columns in general. (Note that 1/DT must be an integer. "By Prescription Only" uses a DT of .25 years, resulting in an array of 5 columns.) The year-start column consists of numerical values for each variable, while the remaining columns contain formulas (equations) referring to other formulas in the same column or, in the case of level variables, to formulas (or numbers) in the preceding column. The first simulation command is simply to recalculate values for the entire array of formulas. The second command copies the year-end column to the year-start column, converting formulas into numerical values as it does so. (This is accomplished using Lotus' data base "extract" command.) In "By Prescription Only", these two commands are executed in about fifteen seconds.

After each year of simulation, the new year-start output values are copied into the appropriate output year range. The player is then shown a new set of annual "Reports" summarizing current evaluative information, an example of which is displayed in Figure 3. After taking note of this information, the player is taken to the "Decisions" display shown in Figure 4 and is asked to make the two decisions he makes annually as "Czar". If an entry is outside the indicated limits or he is not satisfied with his decisions, the computer lets him try again. If everything is fine, Lotus goes back to the simulation step and the lower message in Figure 4 is displayed.

The game continues in this manner until the current year displayed in "Reports" matches the game length for the particular treatment being tested. At this point, the player is taken to the "Game Over" display shown in Figure 5, which presents the final score for the game just played, as well as the best previous score for the specific treatment. A carriage return next brings up the second display in Figure 5, an array describing the characteristics of each treatment in qualitative terms, which allows the player to see how the game just played fits into the overall scheme of things.

Another carriage return and the "Graphs" display presented in Figure 6 appears, along with a menu offering seven graph options as well as the option to quit graphing. When a particular graph is selected (SCORE, for example), a description of that graph is first displayed, as shown in the top half of Figure 7. Another carriage return brings up the requested graph itself. Yet another, and the "Graphs" display and menu reappear. When the player has finished viewing graphs, he selects "Quit" from the

```
-----------------------------------------------------------------------------
  D      As Czar, you now have two decisions to make
         that will affect the medical community this year.
  E      Enter values for both of the decision parameters,
         then indicate if you are satisfied with these decisions.
  C        (Just enter desired value then press RETURN.)

  I      Of the 20,000 physicians who want to         20000  MDs
         use the new treatment, how many are
  S      permitted to use it? (0 - 20,000 MDs)

  I      Of all the recipients currently under         4625  cases
         observation, how many will be formally
  O      evaluated for the public record?
                 (0 -  4625  cases)
  N
         Are you ready to go with these decisions?       1
  S              (1="go", 0="no go")
-----------------------------------------------------------------------------
```

```
Please wait! Lotus is now simulating a year's
worth of activity in the medical community,
using your decisions as input. New evaluative
information will soon be displayed.
```

Figure 4: Annual Decisions and Simulation Message Displays

menu and is bid farewell by the lower display in Figure 6. A final carriage return causes the game selection worksheet to be retrieved so that a new game can be played.

EMPIRICAL NOTES ON GAME DEVELOPMENT

A preliminary version of "By Prescription Only" was tested this February in a class of twenty-three students studying systems analysis as part of USC's master's degree program in systems management. This class had neither experience with system dynamics (except for an introduction to causal-loop diagramming) nor any expertise in the medical or health policy field. Before playing the game, the students listened to a lecture and received a handout covering (1) the issue of emerging medical technologies, (2) the game and the underlying model (including a diagram similar

```
------------------------------------------------------------------
 G    The game is over!  Your final score reflects the relative
      contribution of the new treatment to patient health
 A    over the entire period of emergence (10 or 15 years).

 M    For example, a score of 5.0 means that the new treatment
      improved overall care by 5.0% since its introduction.
 E
      Game Number:                 20

 O    Simulated years:             10

 V    Final score:                0.5

 E    Previous best
      for this game:              0.0
 R
---------------------<Press RETURN to Continue>------------------
```

THE 24 GAMES
(TREATMENTS)

Potential/ Initially mature?	None	Short-term	Long-term	Rare
	Significant Side Effects			
High/yes	1	2	3	4
High/no	5	6	7	8
Moderate/yes	9	10	11	12
Moderate/no	13	14	15	16
Low/yes	17	18	19	20
Low/no	21	22	23	24

Game just played: 20

---------------------<Press RETURN to Continue>----------------

Figure 5: Final Score and Game Array Displays

to Figure 1), and (3) general guidelines on decision-making during the game.

The preliminary game played by the students differed from the current game in one important respect, namely, the requirement that the player make the patient eligibility decision in addition

```
Your game is ready for graphing.  The following
seven graphs are available for display:

G     RECIP:  Recipients (cases per year)
      ELIG:   Patient eligibility fraction (0-1)
R     FRACS:  Product availability fraction,
              Technical maturity index (0-1)
A     TOBSO:  Time allowed for observation of
              outcomes, i.e., follow-up time (years)
P     REFF:   Average relative risk-effectiveness
              (actual and reported)
H     REPRT:  Desired and actual evaluation reports
              (cases per year)
S     SCORE:  Score to date (% benefit relative to no use)

Make your choice from the above menu.  After viewing
a graph, press RETURN and the menu will reappear.
```

```
THE END !   THE END !   THE END !   THE END !

THE END !   THE END !   THE END !   THE END !

THE END !   THE END !   THE END !   THE END !

THE END !   THE END !   THE END !   THE END !

THE END !   THE END !   THE END !   THE END !

      Enter RETURN to play another game
      of "By Prescription Only".
      Good luck and good health!
```

Figure 6: Graph Selection and Final Displays

to the availability and evaluation decisions retained in the current game. Physicians in real life appear to adjust eligibility on the basis of marginal (as opposed to average) health outcomes (Homer 1983); accordingly, both reported average and marginal "relative advantage" (the term used previously instead of "relative risk-effectiveness") were presented in the annual

SCORE TO DATE:
A cumulative measure of the new treatment's relative net benefit to patients making up the patient universe. It is a function of both the cumulative number of recipients and the relative risk-effectiveness of the new treatment for those recipients.

If the relative risk-effectiveness has been greater than 1 for most recipients, the score will be positive. In this case, the more recipients there have been, the higher the score. On the other hand, if the relative risk-effectiveness has been predominantly less than 1, the score will be negative; the more recipients, the more negative it will be.

Enter RETURN to view the SCORE graph.

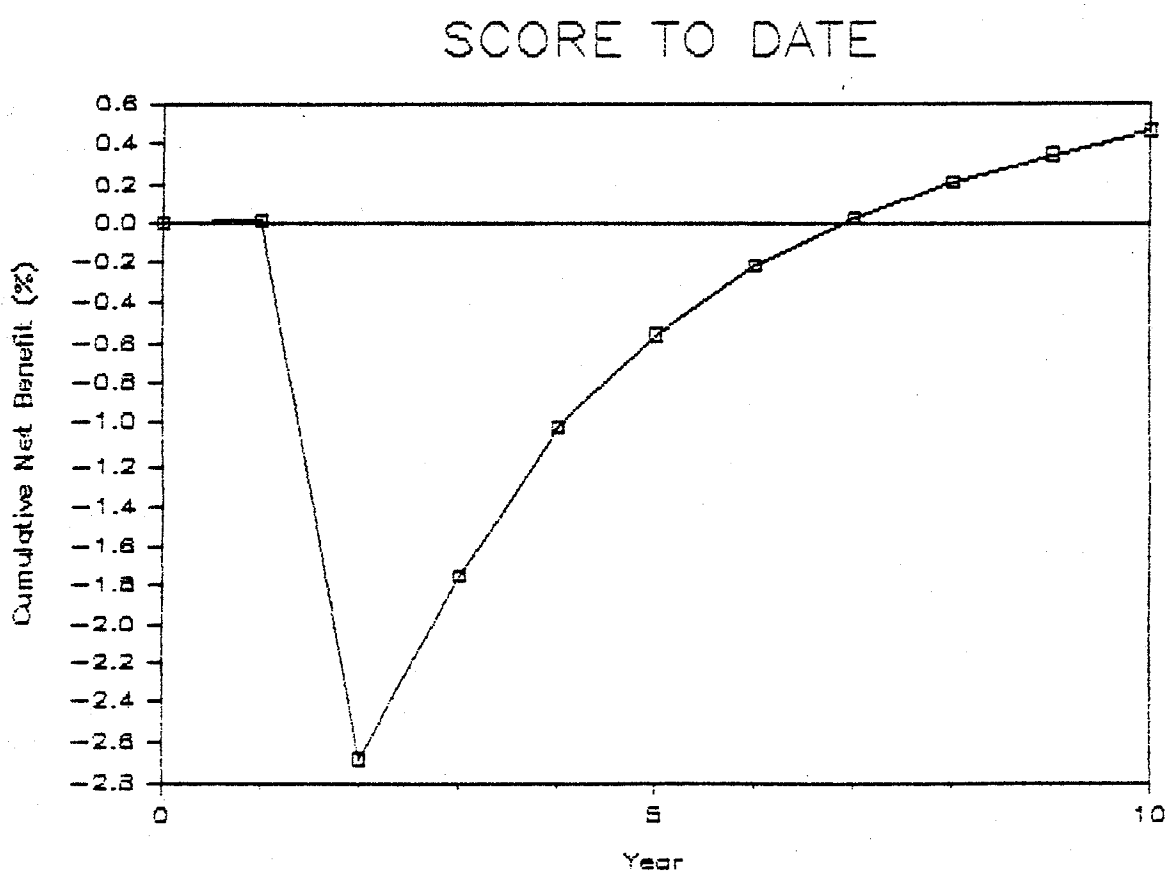

Figure 7: "Score to Date" Information and Graphical Displays

reports display. Not only was the distinction between marginal and average outcomes a difficult concept for this particular class, but even the difference between eligibility and availability proved elusive. Nonetheless, with a bit of coaching, some of the students did catch on to the game and did an adequate job of making the three required decisions.

The students were less than enthralled with the preliminary game not only because of its conceptual complexity, but also for a couple of logistical reasons. First, with only four computer terminals in the classroom, it was necessary to have a team of several students bunched around each terminal trying to make the decisions jointly. This set-up proved to be both physically and socially uncomfortable and appeared to spread and magnify conceptual difficulties, rather than resolve them. Second, the preliminary game had a simulation algorithm taking roughly twice as much time as the current one, resulting in a longer game and more "dead time" between decisions. The fact that only two of the four computers had graphics boards also did not help matters, time-wise. Add to this the time-consuming elements of conceptual confusion and group decision-making, and it is not surprising that each game ended up taking an hour or so. As a result, the students lacked the time necessary to test and modify strategies over the course of several iterations of game play.

The lackluster classroom experience led to several game modifications, including the automation of the eligibility decision, the use of clearer terminology, the substitution of a faster simulation algorithm, and the addition of explanatory messages preceding each graph (as seen in Figure 7). A single player can now go through an entire round of play in fifteen to twenty minutes. But even the current faster and simpler game is not clearly appropriate in a classroom setting, since it does not provide the socially reinforcing experience of a manual game such as the Beer Distribution Game. Instead, it is probably more appropriate in a setting where an individual with particular interest, and perhaps decision-making involvement, in health policy can devote an extended period of time to testing various strategies against different treatments. (See Homer 1981 and Homer 1983 for full-model testing of alternative availability policies; see Homer 1983 for full-model testing of alternative evaluation policies.)

CONCLUSION

The classroom experience described above is, in part, an example of what can happen when a game is designed without thorough consideration of the needs and capabilities of the intended audience. While the preliminary version of "By Prescription Only" successfully circumvented the need to understand system dynamics, it made excessive demands on the player's understanding of concepts in the area of health policy, some of which are familiar to only a handful of individuals. The current version of the game is simpler to understand and has a greater chance for success. But this success will have to come outside the usual classroom setting, where an individual interested in the control of new medical treatments can learn and explore at his own pace and in his own way.

Despite the difficulties involved in developing system dynamics computer games that are both educational and enjoyable for the non-system dynamicist, the material presented in this paper points to the fact that these difficulties can be overcome. Macros, menus, and spreadsheet displays form the basis of the user-friendliness of "By Prescription Only", but non-spreadsheet solutions are also undoubtedly possible. Pursuing the spreadsheet approach further, an intriguing next step would be to develop a standardized game "template" that could speed the process of game development dramatically. A large number of application templates have already been designed as add-on enhancements to Lotus 1-2-3, in almost every general category of business, including finance, marketing, accounting, forecasting, production control, and project management (Carroll 1985). A program that assists system dynamicists in building enjoyable computer games might do much to increase interest in using such games to spread dynamic understanding beyond the realm of dot-JK.

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