Project Management Interactive Learning Sim

Presented at the 2009 PM Challenge

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Outline

- What is the Learning Sim, and how is it used?
- What are the key lessons that are taught?
- Was it successful in its goals?
- What lies “behind the curtain”?

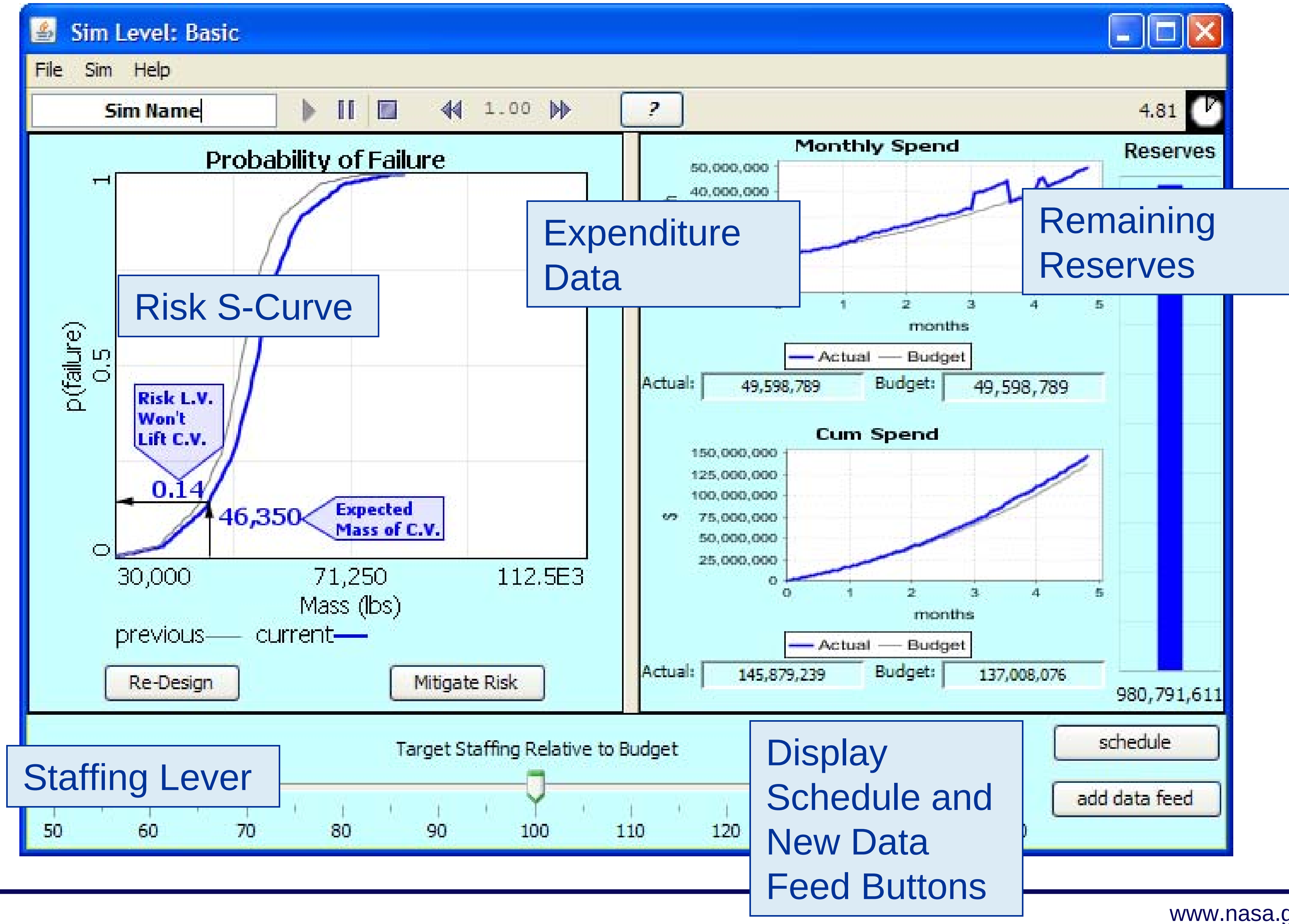
What is the Learning Sim?

- Designed by Ventana Systems, Inc., for NASA to emphasize the Project Manager's need for good data to manage most effectively.
- Being implemented into the APPEL curriculum
- The program is an interactive simulation, where the user assumes the role of a Project Manager for the development of a human-rated rocket
- The program simulates ***people doing work***. This involves simulating (among other things):
  - Progress being made, as well as errors and error discovery
  - Common human behaviors and responses - people working overtime when there's more work to do than regular time allows and suffering from fatigue when overtime is sustained or excessive
  - The effects of worker fatigue on progress being made and the rate that errors are made

What is the User's Goal?

- To successfully complete a run of the Simulator, the user must control the sim to provide the following two outputs:
  - The rocket must have less than a 20% chance of failure of lifting its payload
  - The design team must complete all of the design work

Screenshot of Sim

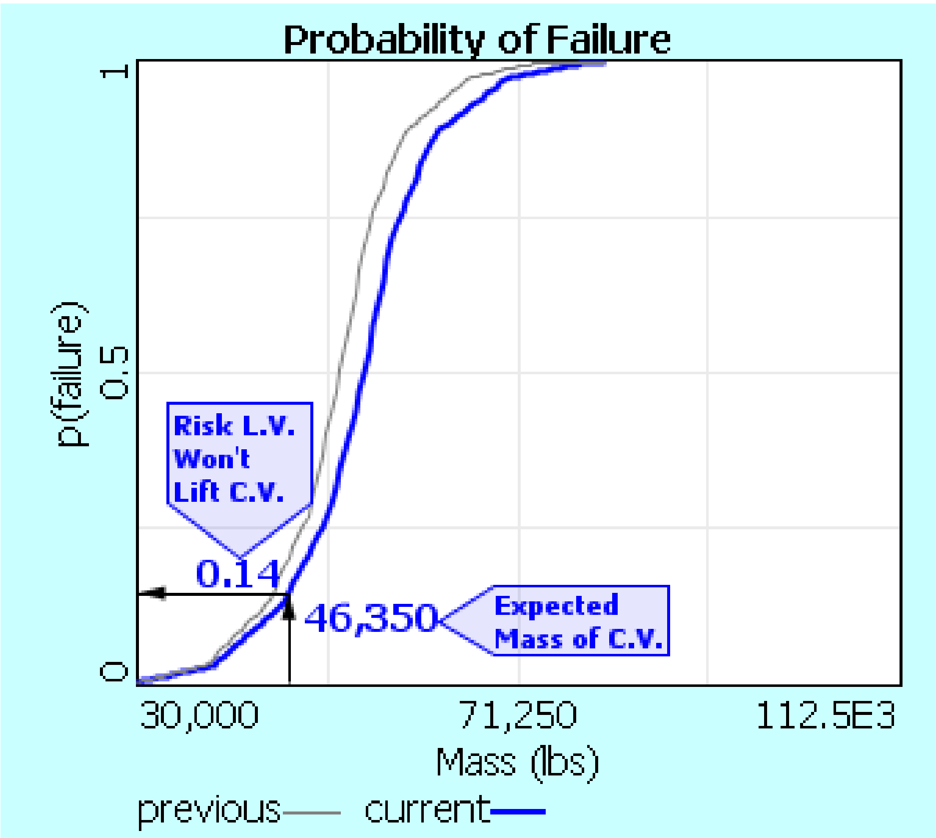


Data Displays

- There are several data displays in the model, some are “free” and part of the basic display, while some of them cost the user money from his reserves pool:
  - Free displays:
    - Current lifted mass probability “S-Curve”*
    - Current and cumulative Expenditures
    - Time left in the design cycle
    - Current mass of the payload (this increases over time)
    - Reserves remaining
  - Displays available for purchase:
    - Staffing
    - Progress
    - Rework Discovery
    - Reserves
    - Overtime

***To be described on the next chart**

The S-Curve



- This curve represents the entire “design” of the rocket for the Simulation. It is a Cumulative Distribution Function representing the probability that the rocket will or will not be able to lift a particular mass
- It is read in the direction of the arrows: the current mass of the Crew Vehicle (C.V.) on this picture is 46,350 lbs. This number falls onto the curve at the 14% probability of failure, implying an 86% probability of success

Controls

- Similar to a real project manager, the user has only a few controls:
  - Can ask her team to redesign the rocket*
  - Can ask her team to mitigate the risk that the rocket will lift a smaller payload*
  - Can increase or decrease staffing
  - In the more realistic levels, the user can modify the schedule somewhat
- The Sim is simpler than real life for several reasons
  - Easier to build
  - Less apt to fool the user into thinking that the sim is "complete"

*****_To be described more fully on the next chart_

The Design Buttons

- Redesign:
  - When the user clicks on this button, $5M is subtracted from the remaining reserves, and the S-Curve shifts to the right
    - This show that the new design can lift more mass
    - Represents a partial redesign of the system. An example might be switching from a four-segment solid rocket to a five-segment solid
- Mitigate Risk
  - When this button is clicked, $4M is subtracted from the remaining reserves, and the left half of the curve moves down.
    - This shows a decrease in the probability of lifting a smaller mass
    - Represents a more minor design change, such as changing to a more thoroughly tested part so that redundancy can be eliminated
- Mitigations are specific to a design
  - Thus any Redesign will delete any Mitigations that have been done

How Do You Win Level One?

- Level of Insight One:
  - To successfully complete the Sim, the user must realize that there are built-in inefficiencies in the labor that is being simulated
  - To understand that the inefficiency is there, it is necessary to open the “Progress” data feed
  - To overcome this inefficiency, it is necessary to increase staffing
  - Simultaneously, the user must successfully use the “Redesign” and “Mitigate Risks” buttons to keep the design at a higher than 80% chance of successfully lifting the payload

How Do You Win Level Two?

- What's Different in Level of Insight Two:
  - Any time the design buttons are pressed, they obviate some of the work that has already been completed
  - The further along in the design, the more work obviated, and the less time to recover from that

- To successfully complete the sim at this level:
  - The user must make a guess at the beginning as to what the final mass the C.V. will be, and perform enough redesigns and mitigations to have the launch vehicle successfully lift that amount of mass
  - If the user guesses wrong, it is nearly impossible to repair the situation near the end of the Simulation

How Do You Win Level Three?

- What's Different in Level of Insight Three:
  - The simulated workers attempt to understand how much work there is to do before a design review
    - If there's too much work, they start working overtime
    - This increases the speed of work, and
    - This also increases their simulated fatigue level
    - High fatigue eventually increases simulated error rate
    - Errors, once discovered, increase the amount of work to do
- To successfully complete this level, more information is needed for managing the simulated workforce:
  - Overtime tracks how many hours are being worked
- Additionally, the user has some control over the schedule
  - This allows two interacting controls to help manage the workforce: if Overtime is too high, the schedule can be extended or more workforce can be hired. Either choice will reduce the error rate within the model

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Lessons Learned – Insight Level One

- It is very difficult to succeed without the "Progress" data feed. With that data feed, it is possible to understand that the project is falling behind schedule and to repair the situation before it becomes intractable
- Do design work up front. It is difficult to recover near the end of a project if you have to do a redesign or even mitigation
- There are two factors that reduce the planned effectiveness of the workforce:
  - There is a built-in inefficiency in the work that is done
  - The model also simulates worker errors. These errors are eventually discovered by the simulated workers, and then have to be corrected before the work is considered done. In essence, this increases the amount of work there is to do.

The Project Manager should manage the actual work that needs to be done, not just "manage to the plan"

Lessons Learned – Insight Level Two

- Do design work up front. Level Two obviates some of the prior complete work when a redesign or a mitigation is done, and thus there is a greater penalty at this level than in Level One for executing redesigns later in the project life cycle.
- It becomes even more important to see the "Progress" metric. Without seeing that some of the progress is reversed by redesign or mitigation, the user is unaware of the negative consequences of continual redesign

The Project Manager should understand when design changes are appropriate and when they aren't

Lessons Learned – Insight Level Three

- If the user pays attention to the worker's average length of workweek, the schedule can become a management tool.
  - Keeps the simulated people from being underworked or getting fatigued by overtime, causing errors to be made that will need later correction
  - Demonstrates that the "Overtime lever" that most project managers think will help is, in the long run, *always* less effective than thought—in fact, it can be detrimental to the project if used too often or for too long
  - Also demonstrates the need for more data—without good data, it is difficult or impossible to determine the effect that the current schedule is having on the workforce

The project manager should understand when to slip the schedule and when not to slip – pushing too hard will get a poor result

Meta-Lessons

- Without data, it is difficult to manage effectively
- Progress Metrics are potentially the most important
- Metrics that measure fatigue (a very difficult thing to measure) are also important
  - Fatigue can set off a “death spiral” – a reinforcing loop, as described on slide 12
  - Once that reinforcing loop is triggered, it is difficult to recover, and difficult to ensure an error-free product
  - While not measurable directly, Fatigue can be approximated by proxies such as overtime hours or the number of keycard entries or computer logins during the weekend

Metrics

- Unlike the Sim, in the real world progress is difficult to measure.
- Metrics change by phase:
  - In formulation, the # of requirements written, the # of requirements linked, and the number of broken links to work down might be appropriate
  - In development, the number of pieces of hardware built and integrated may be too granular, but it's a very good measure of progress; more likely metrics might be drawings complete, and drawing revisions would indicate how much rework is being discovered and corrected

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Testing Methodology

- There were ten NASA Civil Servant participants of varying experience and age
- Each participant in the test provided information on demographics prior to participating
- Each participant was also interviewed over the phone before playing the Sim
- The participants then spent time playing Insight Level One of the sim
- Finally, they participated in an exit interview
- The substantive questions were not asked until the “after” survey or interview, so as to not lead the participant to a particular answer before experiencing the Sim

Demographics Questions

- It was thought that certain backgrounds might influence the Sim's effectiveness, so the demographic questions were to determine:
  - Degree of comfort/familiarity of users with sim or computer gaming environments
  - Age affects, though perhaps mediated largely by the familiarity effects mentioned above
  - Highly experienced project managers might be differentially impacted by the sim

Demographics of Testers

- Age distribution:
  - 4 were in their 20's
  - 2 in 30's
  - 1 in 40's
  - 3 in 50's
- Center distribution:
  - 5 from Langley
  - 2 from Marshall
  - 2 from Goddard
  - 1 from Johnson
- 5 identified themselves as engineers
- Widely distributed in simulation/gaming experience, project management experience, years of experience and grade level

Findings

- 50% said they learned a lot from the Sim and they would think about the lessons learned in future projects
- 50% said the Sim did not help and they would do nothing differently
- Experience with computer sims/games was not correlated to the results
  - The Sim can be useful to people of varying experience
- Youth was correlated with learning a lot from the Sim
  - The Sim seems to help younger more
- Experience was highly correlated with learning
  - The Sim seems especially useful for helping those with less experience

Interview Notes

- The highly experienced project managers mentioned in the exit interview that they already knew that project metrics were very important
- Inexperienced people, in the introductory interview, did not mention progress metrics as important. In the exit interview, however, participants reported being struck by how important those metrics are for completing the Sim successfully
- All participants became engaged while playing the Simulation—a key aspect of learning
- It is possible that the higher levels of the Sim, especially level three where schedule manipulation becomes a project management tool, would provide learning opportunities for more experienced people. However, this remains to be researched.

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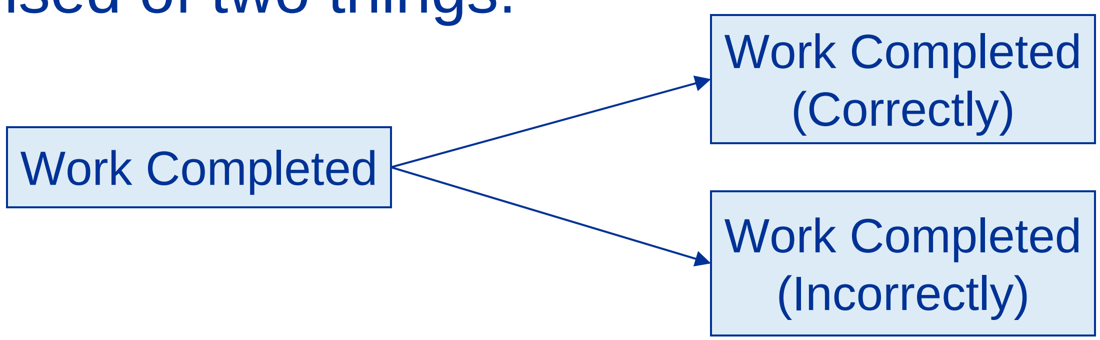
The Basic Model

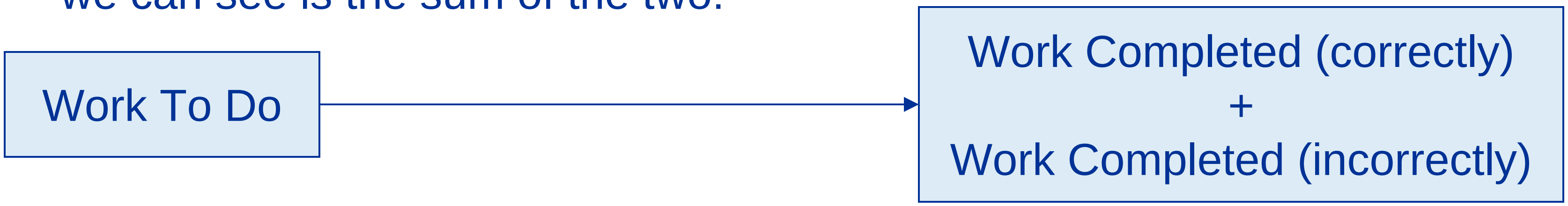
- We tend to think of a project in a simplistic way:

- Once all the work flows from the "inbox" to the "outbox", we're done
- That's true, to an extent. However, when we look at what we've done so far, the "work completed" box is comprised of two things:

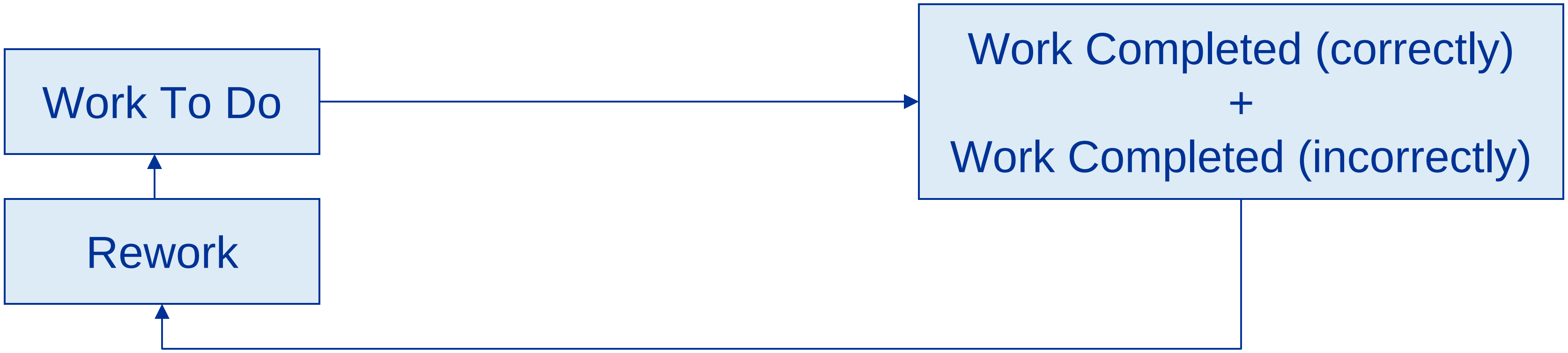


The Basic Model, continued

- Incorrectly done work is eventually discovered, but until then, all that we can see is the sum of the two:



- Once discovered, the incorrect work becomes “rework”—subtracted from the box of completed work, it becomes part of the work left to do:



- We leave rework in its own box because rework often must be completed before original workflow can fully resume

The Basic System Dynamics Model

- In System Dynamics, the modeling language used for this simulation, the diagram above is a (very high level) picture of the mathematical model.
- The boxes are called "stocks", and the arrows are "flows." Flows add to and subtract from stocks; in essence, a picture like this represents a series of interconnected simple differential equations
- Equations are added for each stock and flow to model the system. They can be tied to each other, as well. For example, in Level of Insight 3, the fraction of work that is done correctly is **decreased** when **fatigue** kicks in
- The actual model in the Simulation is much more complex, but it is based on the work-rework cycle shown here. The next page has a snapshot of part of the full model

Fatigue

Example equation:
quality = base quality * fatigue effect on quality * out of sequence effect on quality