Systems Optimization and Analysis (15.066J)

Simulation Module

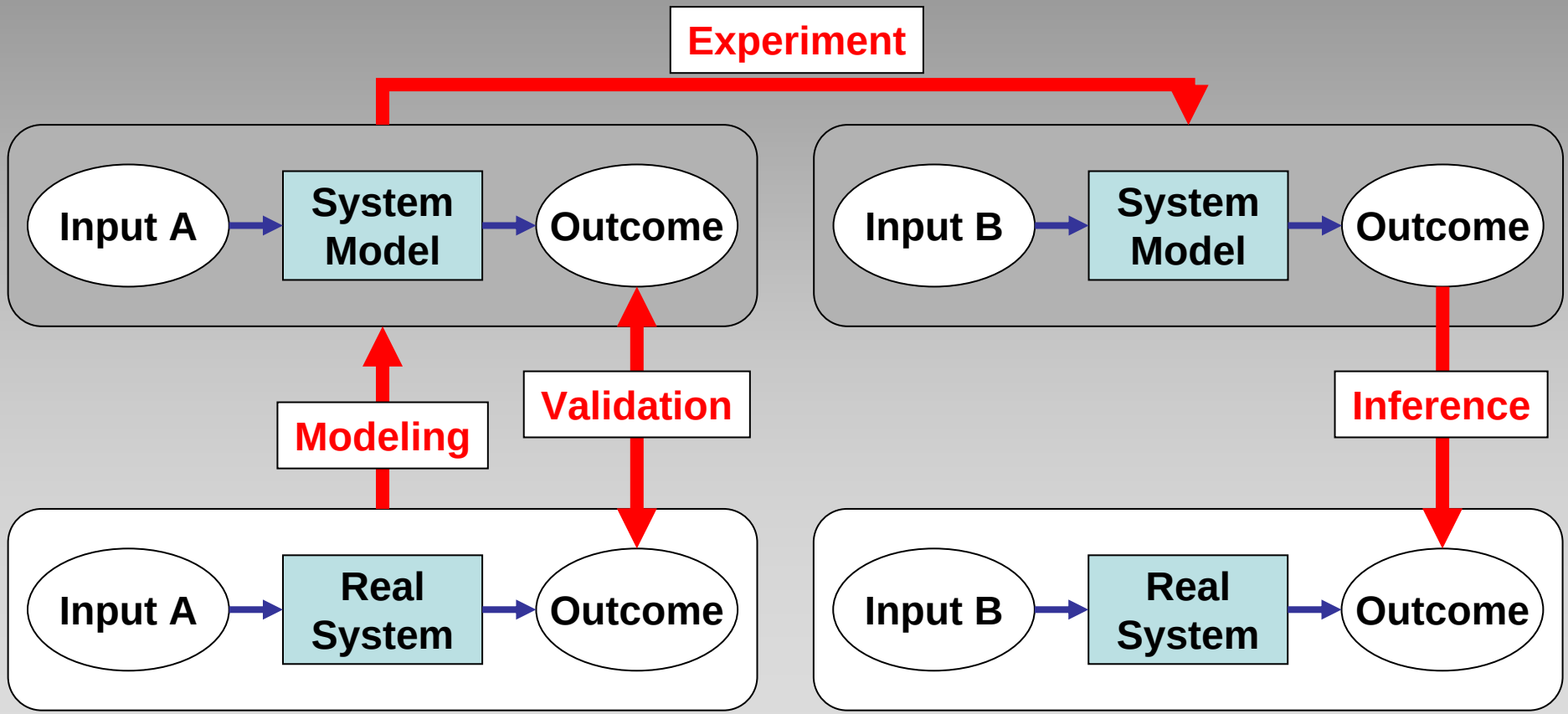
Professor Jérémie Gallien
Operations Management Group,
MIT Sloan School of Management

Bio

- **Eng.D in Production Systems from Ecole des Mines de Paris, France**
- **Ph.D in Operations Research from MIT**
- **Research: Manufacturing Revenue Management, Dynamic Pricing, Auctions, Procurement, Scheduling…**
- **Experience in eCommerce Fulfillment, Electronics, Aeronautics, Transportation and Software**

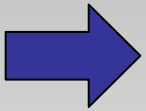
What is Simulation?

- **Application Domains: Science, Justice, Engineering, Education, Entertainment, Management…**



Types of Simulation

- **Physical Vs. Digital**
- **Static Vs. Dynamic**
- **Discrete Event Vs. Continuous Time**



This Module: Digital, Static & Dynamic Discrete Event Simulation

Simulation Module Goals

- **Develop the practical skills necessary to design, implement and analyze discrete-event simulation systems;**

  ➡ **Practice of Modeling!!!**

- **Cover the basic theory underlying discrete-event simulation methods.**

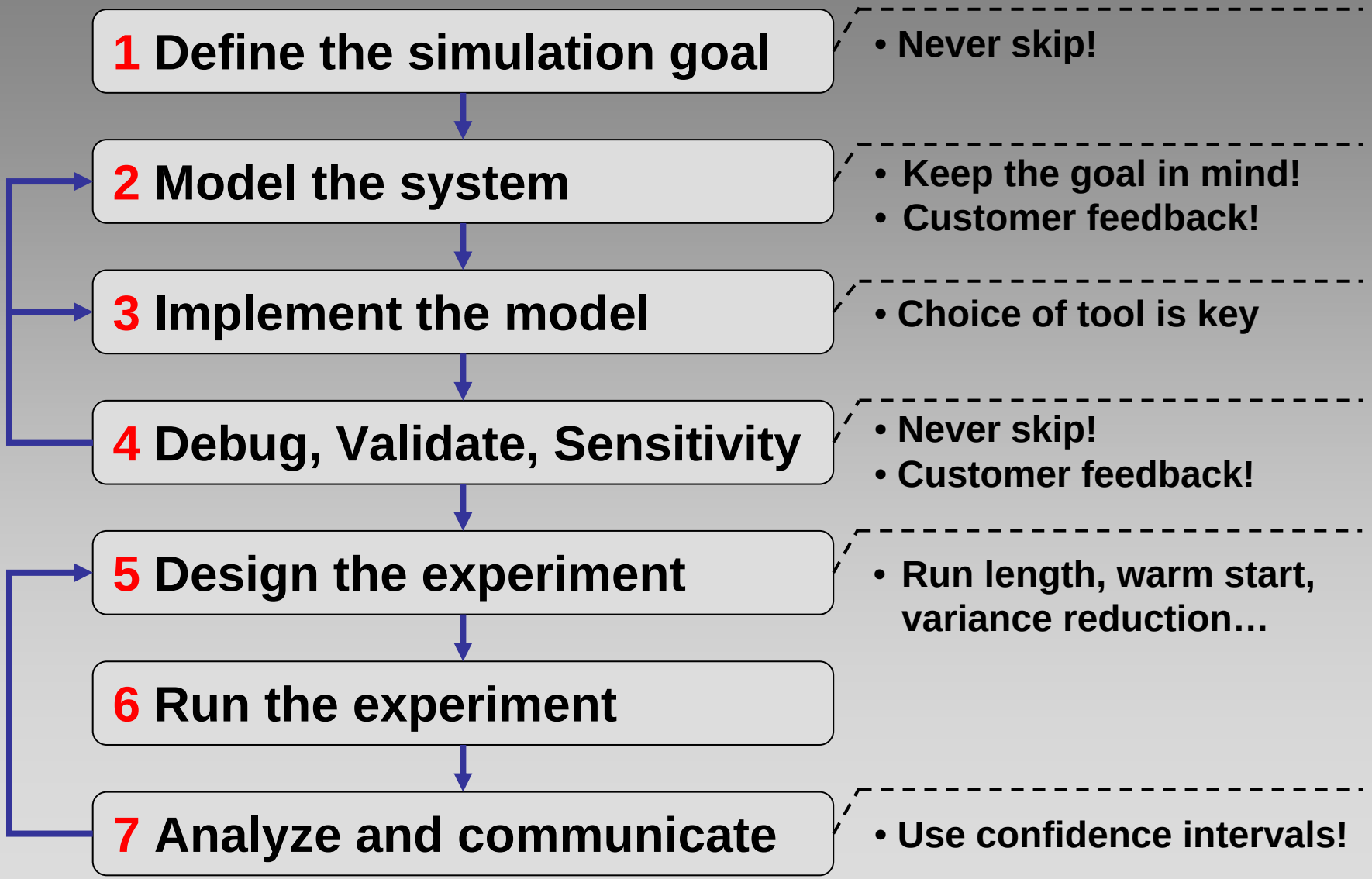
Simulation Module Outline

Week	Class	Date	Topic	Reading	Assignment
1	1	15-Jul	Introduction, Simulation Process and Stochastic Modeling	ClearPictures, Inc.	Questions 1 to 3 in ClearPictures, Inc.
	2	16-Jul	Monte-Carlo Theory and Examples (with Crystal Ball)		Proba/Stat Review 1 Checklist
	TUT1	17-Jul	Monte-Carlo Modeling and Crystal Ball Tutorial		Homework 1
2	3	21-Jul	Ontario Gateway Case Discussion		Ontario Gateway Case Write-Up
	4	22-Jul	Discrete-Event Framework and Examples (with Simul8)	Introduction to Simul8	Implement ClearPictures model in Simul8
	TUT2	24-Jul	Discrete-Event Modeling and Simul8 Tutorial		Homework 2
3	5	28-Jul	Discrete Event Case Discussion		Human Genome Case Write-Up
	6	29-Jul	Experimental Design and Simulation Analysis		Proba/Stat Review 2 Checklist
	7	30-Jul	Advanced Modeling Examples, Simulation-Based Optimization		
	TUT3	31-Jul	Experimental Design and Simulation Analysis Tutorial		Homework 3

Optional References

- **Law, A. and W. Kelton, *Simulation Modeling and Analysis*, 3rd ed., McGraw-Hill (2000).**
- **Ross, S., *Simulation*, 3rd ed., Academic Press (2002).**
- **Swain, J., "Power Tools for Visualization and Decision-Making," OR/MS Today, February 2001. Available online at *http://www.lionhrtpub.com/orms/surveys/Simulation/Simulation.html***

The Simulation Process



Simulation Goal

System Design Vs. System Analysis

Strategic?

Tactical?

Control?

Key Performance Measures?

- **What about ClearPictures, Inc.?**

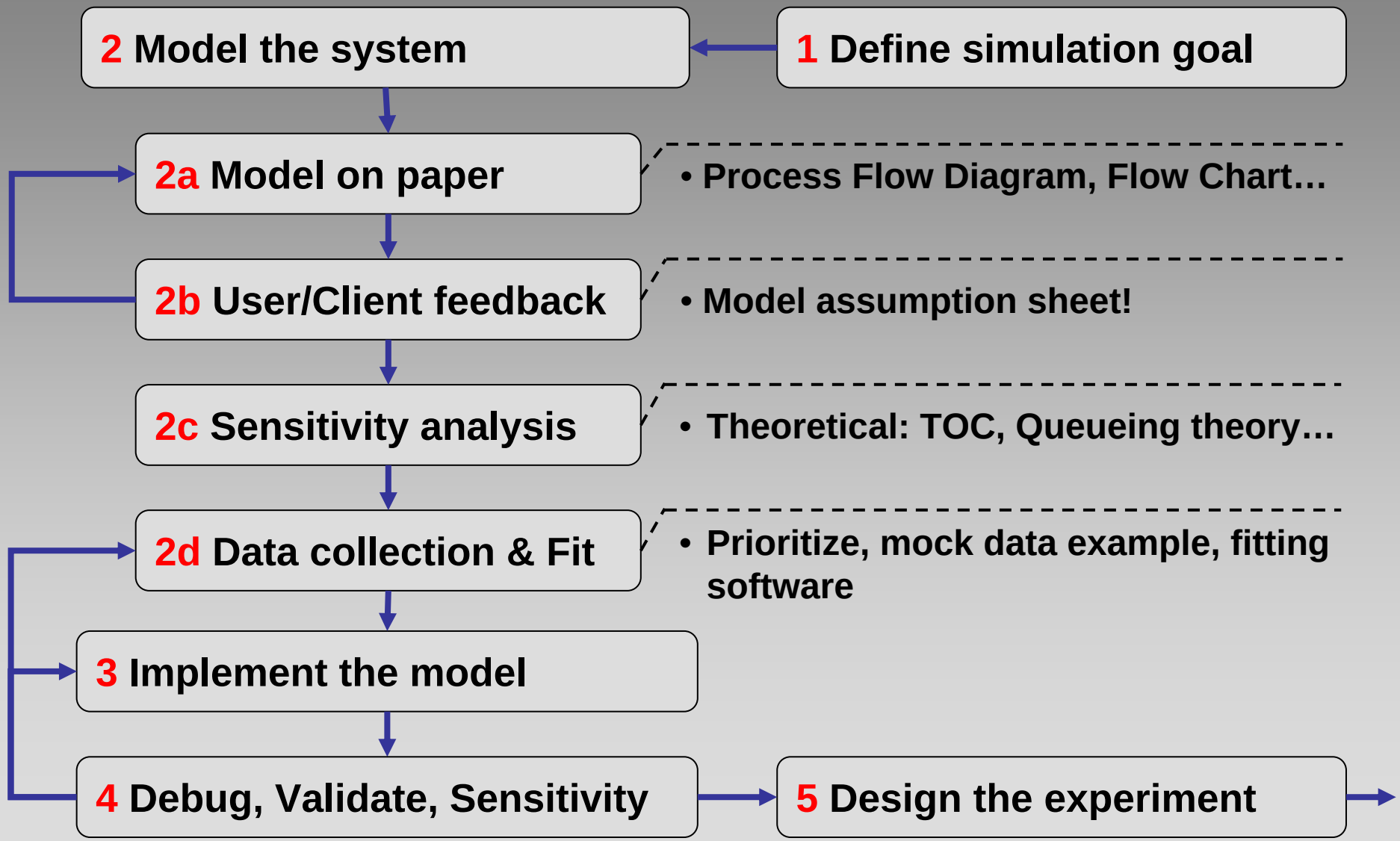
ClearPictures: Simulation Goals

- **Estimate the average and standard dev. of delivery leadtime through the pull section;**
- **Estimate the average and standard dev. of WIP inventory through the pull section;**
- **Determine the production bottleneck;**
- **Estimate the impact of purchasing more machines on leadtime and inventory;**
- **…**

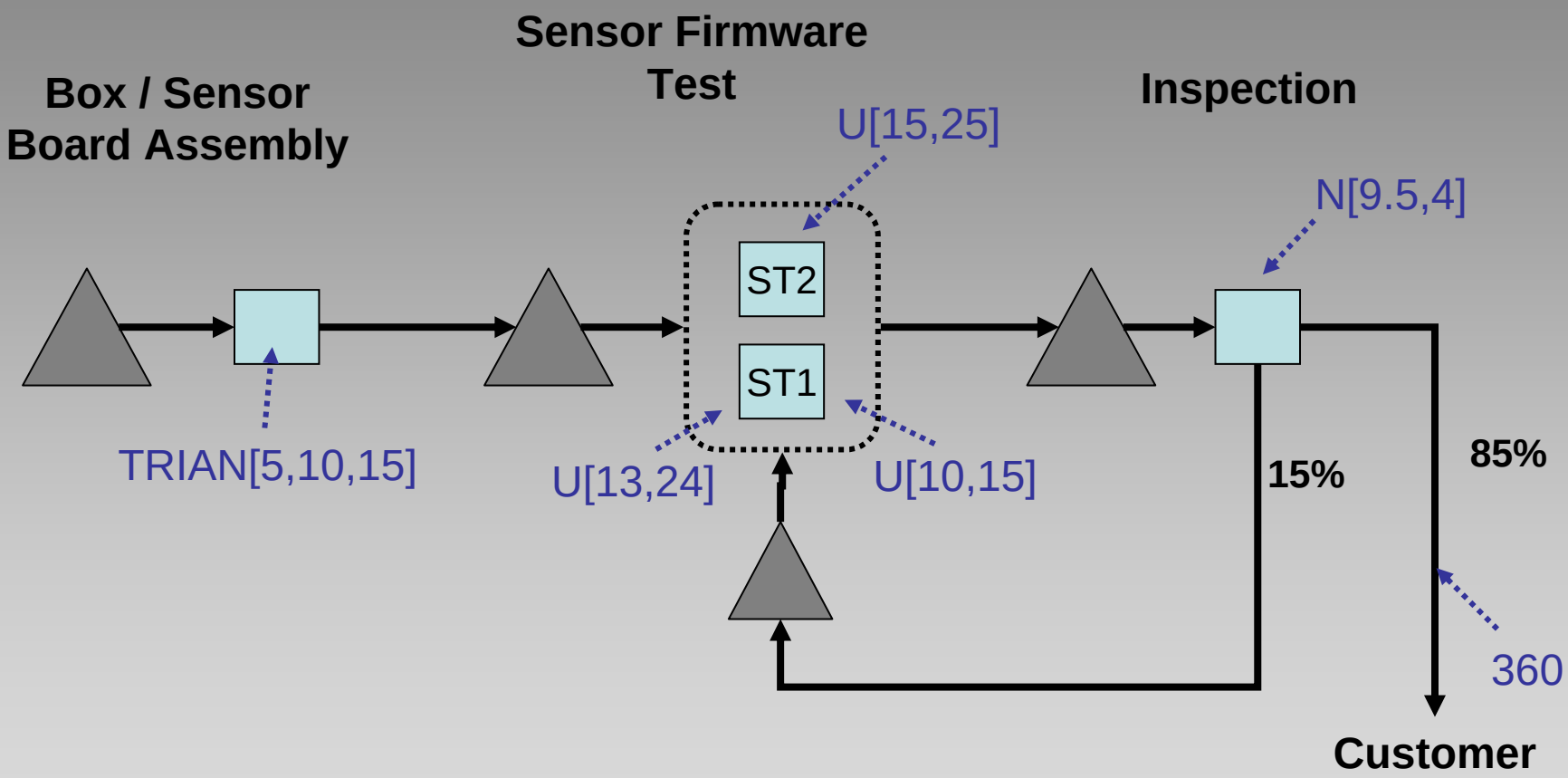
System Modeling

- **“Everything should be made as simple as possible, but not simpler.” *Albert Einstein*.**
- **The simulation goal should be the guiding light when deciding what to model**
- **Get client/user feedback early, and maintain model + assumption sheet for communication purposes**
- **For random variables, collect data and fit distributions… *after* modeling the system, with sensitivity analysis in mind!**

System Modeling



ClearPictures Production Model



Model Implementation

- **General programming language (C++, Java…)**
- **Simulation-oriented language (MODSIM…)**
- **Simulation software with GUI (Simul8®, Witness…)**
- **Excel Add-in (Crystal Ball, @Risk…)**

	FLEXIBILITY	COST	REQ. SKILLS	DEV. TIME	RUN TIME
General Prog. Language	Very High	Low	Very High	High	Low
Simulation Language	High	High	High	Medium	Low
Simulation Software	Medium	High	Medium	Low	Medium
Excel Add-in	Low	Low	Low	Lowest	High

Validation & Debugging

- **Slow Graphical Animation**
- **Step-by-step event list**

Experiment Design

- **Warm-up Period?**
- **Run Length?**
- **Number of Trials?**
- **How to analyze and interpret the results?**

Class 1 Wrap-Up

1. **Simulation Process**
2. **Modeling**
3. **Choice of simulation tool**