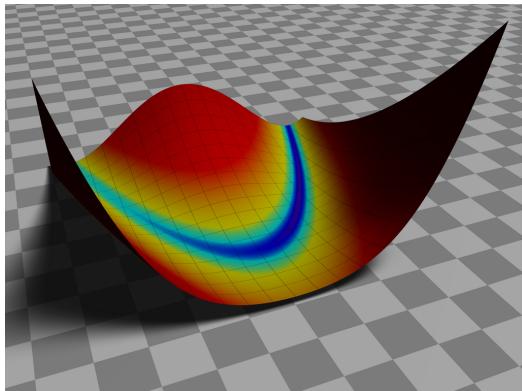


# Introduction

## Lecture 1



ME EN 575  
Andrew Ning  
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## Outline

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### Syllabus

### Optimization Basics

### Examples (from past students)

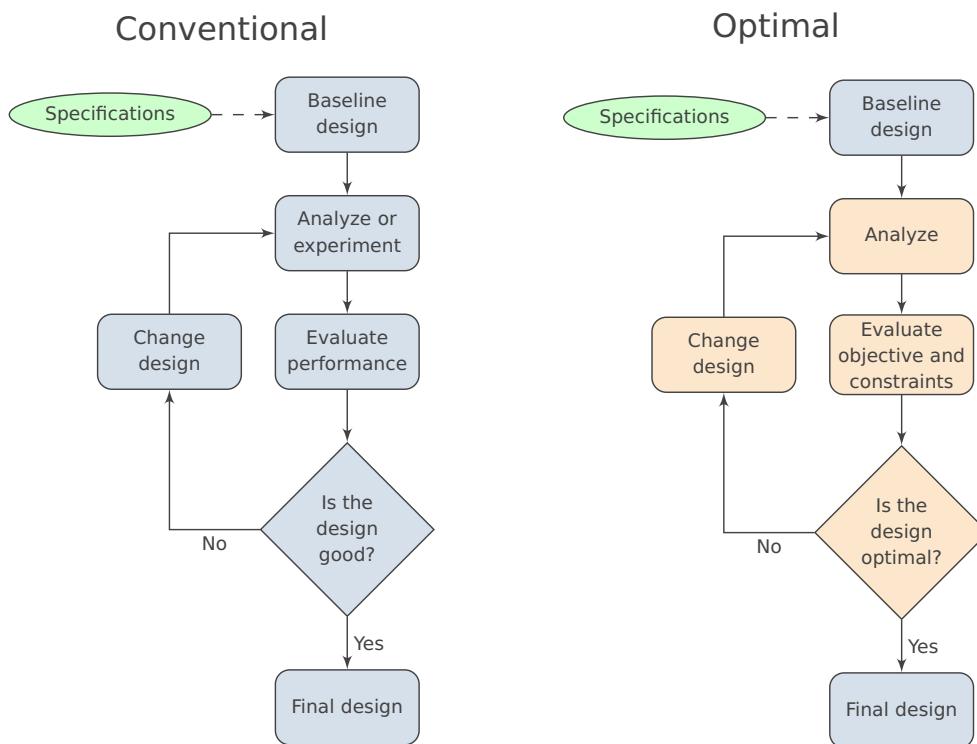
# Syllabus: Some Important Points

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- Make sure your email is current on Learning Suite
- Prerequisites
- Matlab or Python
- Must not refer to homeworks from prior students
- Project
- Weekly Quizzes
- Piazza
- Discussion Session?
- Ask Questions!

## What is Optimization?

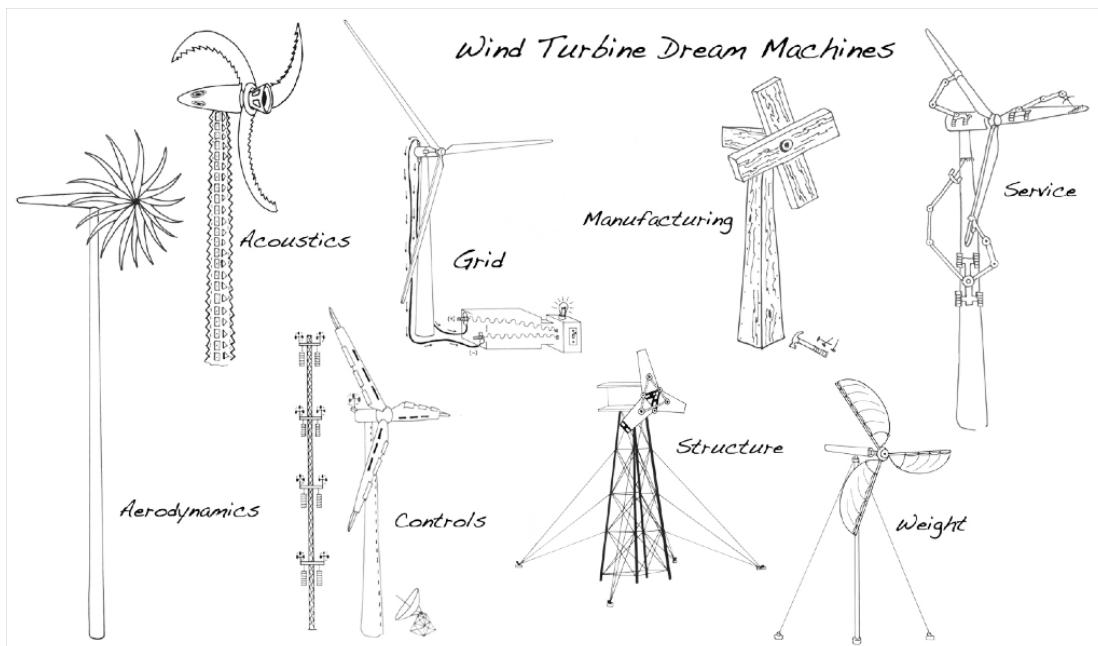
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# Objective Function

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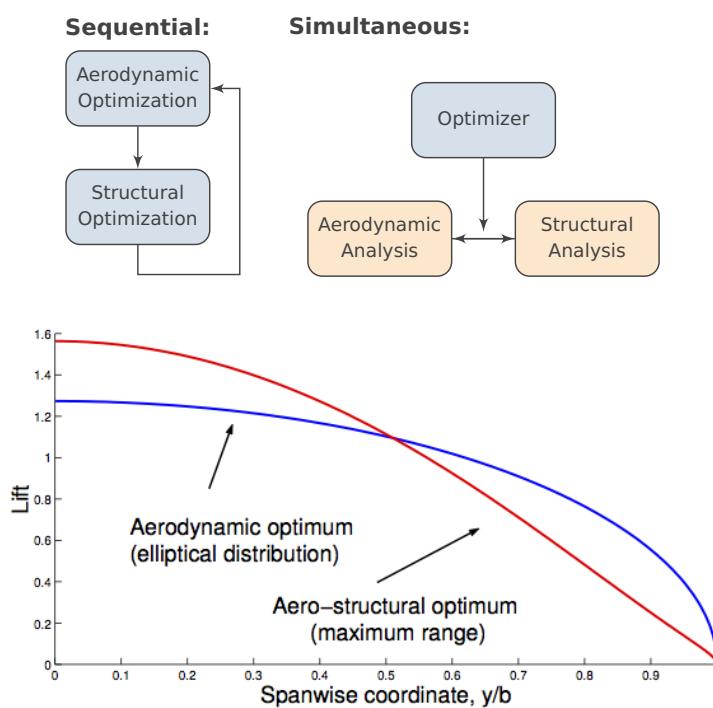
- An objective defines what we mean by “best”. It enables us to compare two designs quantitatively.
- If we select the wrong goal, it doesn’t matter how good the analysis is, or how efficient the optimization method is. Therefore, it’s important to select a good objective function.
- This is not an easy problem, even for experienced designers.



- An objective function may be linear or nonlinear.
- We will represent the objective function by the scalar  $f$  or  $J$ .
- Our convention will be to **minimize** the objective.
- Question: What if you want to maximize?
- Question: What if you have multiple objectives?
- Question: What if you have multiple disciplines?

## Multidisciplinary Optimization

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- Sequential optimization does not lead to the true optimum.
- Need a truly multidisciplinary objective

$$\text{Range} = \frac{V}{c} \frac{L}{D} \ln \left( \frac{W_i}{W_f} \right)$$

- Achieving the proper trade-off requires **simultaneous** optimization.

## Design Variables

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- Design variables, also known as decision variables, are the variables in the problem that we allow to change in the optimization process.
- Optimization is the process of choosing the design variables that yield an optimum design.

- Represented by the vector  $x$ .
- Design variables should be **independent** of each other.
- Design variables can be **continuous** or **discrete**. Discrete variables are sometimes called **integer variables**.

## Constraints

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- Few practical engineering optimizations problems are unconstrained.
- They may be **equality** or **inequality** constraints.
- At a given design point, constraints may be **active** or **inactive**. This distinction is particularly important at the optimum.

- Constraints on the design variables are called **bounds** and are easy to enforce.

$$lb \leq x \leq ub$$

- Like the objective function, constraints can be linear:

$$Ax \leq 0$$

or nonlinear:

$$c(x) \leq 0$$

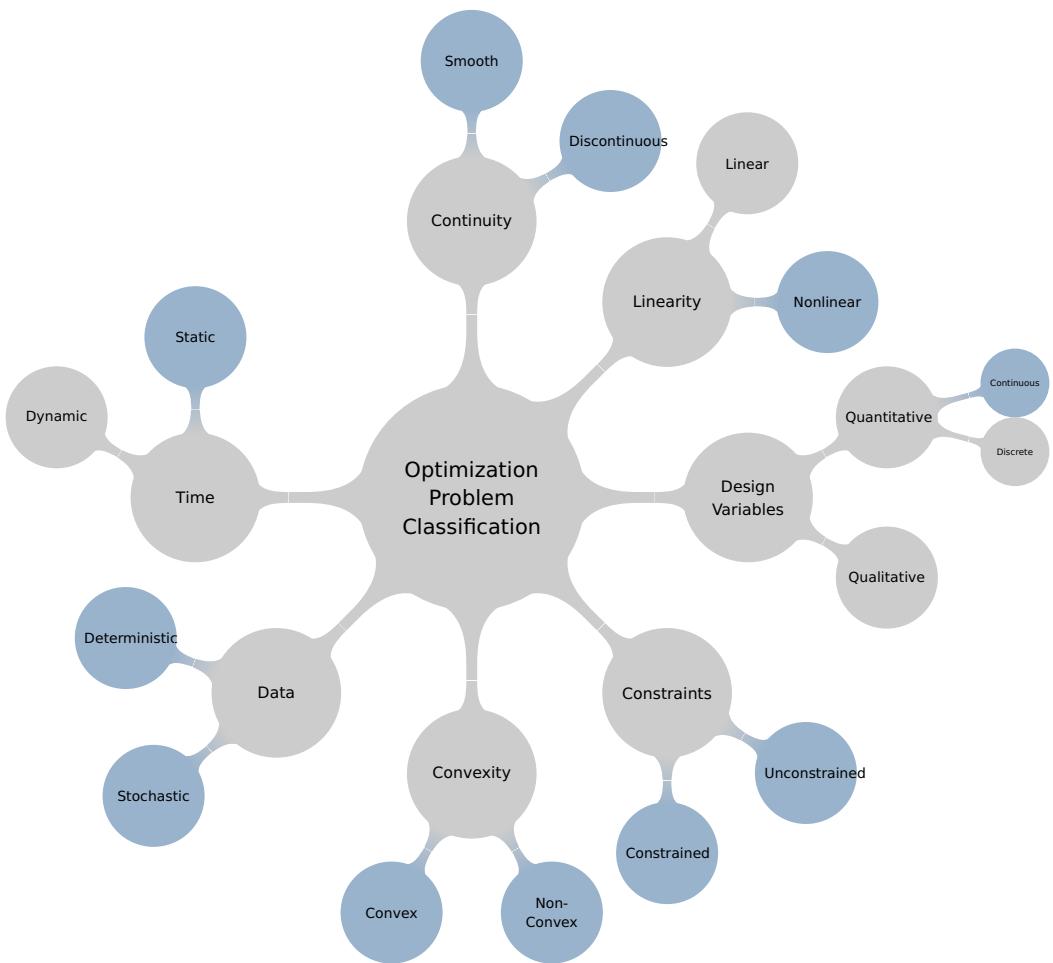
## Optimization Problem Statement

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Objective function, design variables, and constraints form the optimization problem statement:

$$\begin{aligned} & \text{minimize} && f(x) \\ & \text{with respect to} && x \in \mathbb{R}^n \\ & \text{subject to} && \hat{c}_j(x) = 0, \quad j = 1, 2, \dots, \hat{m} \\ & && c_k(x) \geq 0, \quad k = 1, 2, \dots, m \end{aligned}$$

- $f$ : objective function, output (e.g., structural weight).
- $x$ : vector of design variables, inputs (e.g., aerodynamic shape); bounds can be set on these variables.
- $\hat{c}$ : vector of equality constraints (e.g., lift); in general these are nonlinear functions of the design variables.
- $c$ : vector of inequality constraints (e.g., structural stresses), may also be nonlinear and implicit.

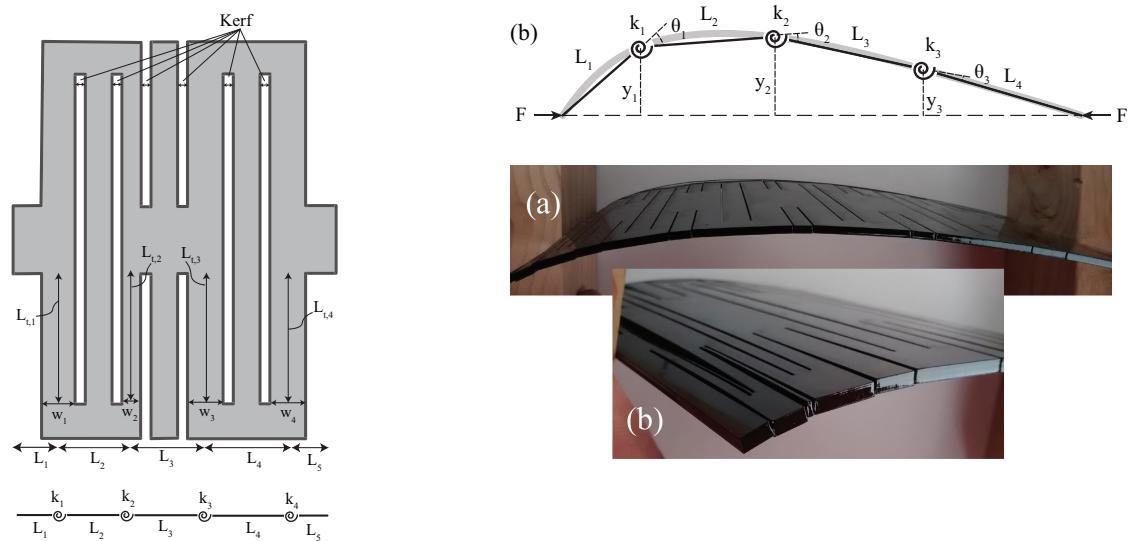


# Optimization Methods

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- **Convex:** These are ideal. Straightforward to solve, provable global optimum.
  - **Integer or Mixed Integer:** Heuristic based. Generally only effective with “convex” problems, or rapid analyses.
  - **Gradient-Free:** Robust, useful with discrete variables. Effective only with small to modest number of design variables.
- 
- **Response surfaces:** Useful for noisy functions (that you cannot change), but requires a large number of evaluations to create fit.
  - **Gradient-based:** Most efficient, especially for large number of design variables. Objectives and constraints must be smooth functions. Even better if you can supply the gradients.

## Cylindrical surface with tailored stiffness



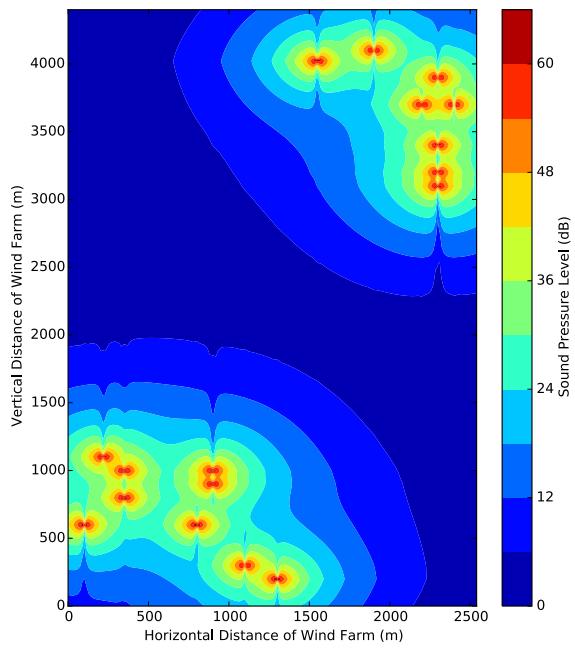
Todd Nelson and Jared Bruton

## System evolvability of a cookstove



Jeff Allen and Kendall Thacker

# Wind farm power and acoustics



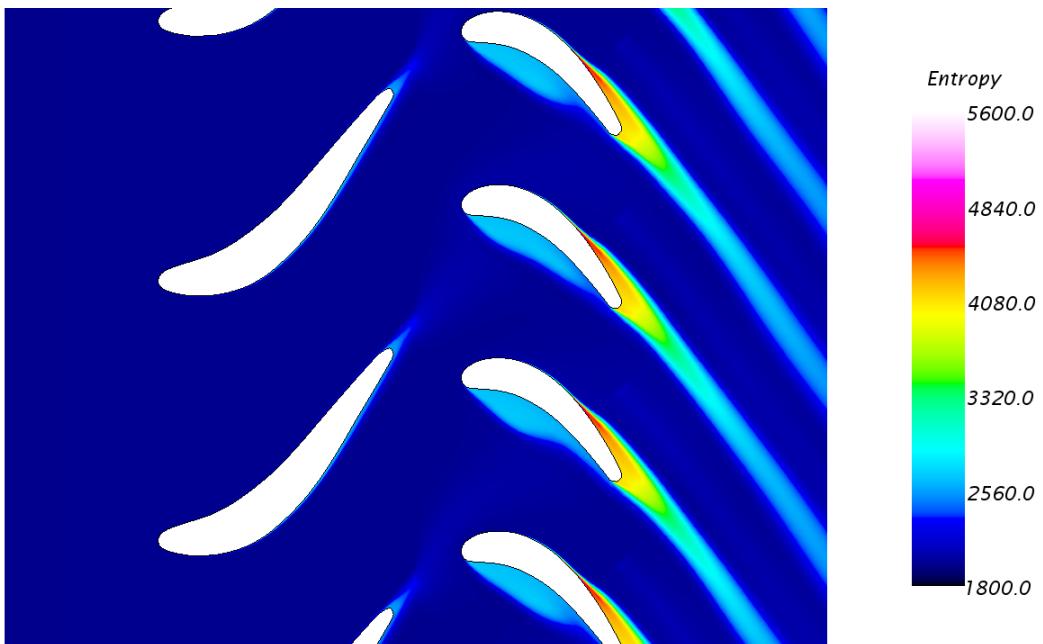
Jared Thomas and Eric Tingey

# Optimized schedule simulator for students

	Sun 2/15	Mon 2/16	Tue 2/17	Wed 2/18	Thu 2/19	Fri 2/20	Sat 2/21
	GMT-07						
▼ My calendars							
Exams	6am - Breakfast	6:30 - Breakfast	6 - Breakfast	6:30 - Breakfast	6:30 - Breakfast	6 - Breakfast	6 - Breakfast
Family		7 - 8 Homework	7 - Homework	7:30 - Homework			
Homework		8 - 10 Work/Research	8 - 10 Work/Research	8 - Project			
Meals			9 - 10 School		9 - 10 Exam		9 - 10 Side jobs
Projects							9:30 - Homework
School		10 - 11 School	10 - 11 Exam	10 - 11 School	10 - 11 School	10 - 11 School	10 - 11:30 Homework
Sleep		11am - 12p School	11 - 1p Work/Research	11 - 12p School	11 - 1p Work/Research	11 - 12p School	
Work 1		12p - 1p Work/Research		12p - 1p Work/Research		12p - 1p Work/Research	
Work 2		1p - Project	1p - Homework	1:30p - Lunch	1:30p - Homework	1p - Lunch	1p - Lunch
	1:30p - Lunch	2p - 3p Work/Research	2p - 3p Work/Research	1:30p - 3:30p Homework			
	3pm	3p - 4p School	3:30p - 6:30p Homework	3p - 4p School	3p - 4p School	3p - 4p School	
	4pm	4p - 5p Side jobs	4p - 5p Homework	4p - 5p Homework	4p - 5p Homework	4p - 5p Project	4p - 5p Project
	5pm	5p - 6p Family	5p - 6p Homework	5p - Project	5:30p - 7p Homework	5:30p - Project	5p - Homework
	6pm	6p - 7p Dinner	6p - 7:30p Dinner	5:30p - 6:30p Dinner			
	7pm	7p - 8:30p Homework	7p - 8p Dinner	7p - 8p Dinner	7p - 8p Dinner	7:30p - Homework	
	8pm	8:30p - Project	8:30p - Homework	8p - 9p Homework	8:30p - 9:30p Side jobs	8p - 9p Homework	8p - 9p Family
	9pm	9p - 10p Family	9p - 10p Family	9p - Family	9:30p - Family	9:30p - Family	
	9:30p - Family	=					

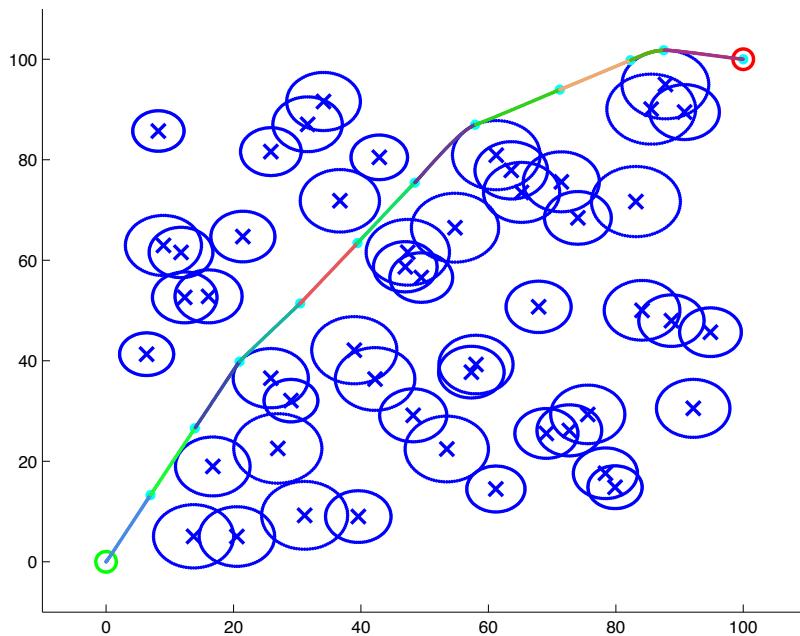
Sam McDonald and Dallin Swiss

# Shape optimization of turbine geometry in pulsing flow conditions



Mark Fernelius

## UAV Path Planning



Kyle Ingersoll, Patrick DeFranco, and Bryce Ingersoll

## Fantasy baseball

NAME	POSITION	SALARY	PPG
MATT WIETERS	C	3	3.3846
JUSTIN MORNEAU	1B	1	3.1407
NOLAN ARENADO	2B	13	3.2522
NEIL WALKER	3B	7	3.1678
ERICK AYBAR	SS	4	2.6346
GEORGE SPRINGER	OF	18	3.5384
JAYSON WERTH	OF	5	3.4082
GIANCARLO STANTON	OF	41	4.1310
JORGE SOLER	OF	4	3.7083
COREY DICKERSON	OF	23	3.3206
BEN ZOBRIST	2B	4	3.0136
CARLOS SANTANA	1B	4	3.2894
AVISAIL GARCIA	OF	1	2.9565
RUSNEY CASTILLO	OF	1	3.7532
KEN GILES	RP	1	3.2694
MICHAEL MANTUA	SP	12	3.6500

Cameron Jones and Scott Jackson