

Statistical Collaboration at NASA

The Art and the Science

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Langley Research Center

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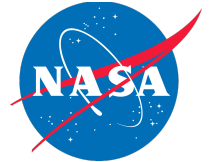
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University of Waterloo

Department of Statistics and Actuarial Science

Statistical Consulting (STAT 938) Guest Speaker

NASA Langley Research Center



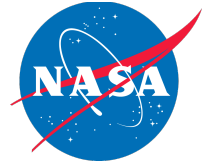
- **One of 10 NASA Centers, located in Southeast Virginia**
- **Established in 1917 as first civilian aeronautics laboratory in the U.S.**
- **Initial home of the first astronauts (Mercury 7)**

Today, we focus our research on challenges across:

- **Space Exploration**
- **Aeronautics and Air Transportation**
- **Atmospheric Science**



My Background



- B.S. in Mechanical Engineering, 1989
- M.S. in Applied Physics and Computer Science, 2000
- M.S. in Statistics, 2003
- Ph.D. in Statistics, 2005
- Licensed as a Professional Engineer, 1997

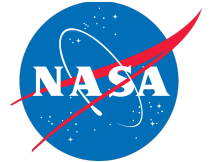
Professional Experience: NASA Langley Research Center, 1997 – present

- Serving as Agency-wide statistical expert
- Team Lead, Advanced Measurement Systems, Statistical Engineering Team
- Modern Machine and Tool Company, 1989 – 1997
 - Instrument system design and production for industry and aerospace
- Edward W. Face Company, 1986-1989
 - Concrete construction consulting and high-precision flatness measurement

Academic Experience: Mentored over 30 students, 10 thesis/dissertations, at 5 universities Aerospace Engineering, Mechanical Engineering, Statistics, Operation Research, and Industrial Systems Engineering

Professional Service: Editor-emeritus of Quality Engineering, Past-Chair of ASQ Publications Management Board, Chair-Elect of International Statistical Engineering Association, member of ASA, ASQ, AIAA

An Engineer's Statistical Awakening



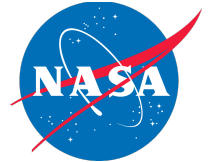
- Traditionally, academic training of engineers lacked relevant, applicable, practical courses in statistics (*that's me*)
 - Engineers are generally trained to “fear” uncertainty
- In 1999, I stumbled upon a 20-year old NASA report from a visiting statistics professor that proposed “radical” ideas and promised significant schedule and cost benefits.

A few “radical” statistical concepts

- Experimental Design starts with questions, not data
- Factorial Experiments are efficient for learning, not chaotic
- Modeling is more than plotting to discern subtle differences

Discovered “new” statistical techniques to efficiently learn and gain deeper insights

Space Launch System Development



Shuttle



Ares I



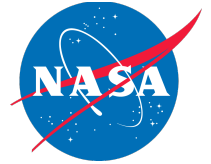
Flight Test



**Full-Scale
Static Firing**



Distinguishing Collaboration



Consultation

Helping others understand a pre-defined problem in a larger system

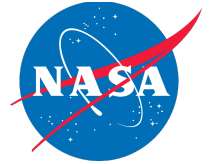
Cooperation

Dividing a task among team members, where each person is responsible for a portion of the problem solving

Collaboration

Mutual engagement to identify and solve a problem together with a common goal

Spectrum of Statistical Practice

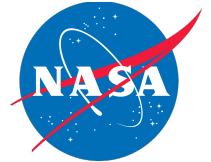


Consultant: “Journeyman statistician **takes the problem the consumer presents, fits it into a convenient statistical conceptualization**, and then presents it to the consumer – journeyman prefers **monologue**.”

Collaborator: “Master statistician **hears the problem from the consumer’s viewpoint, discusses statistical solutions using the consumer’s language ...**, and arrives at statistically based recommendations or conclusions ... new conceptualizations collaboratively - master statistician relies on **dialogue**.”

“Effective statistician is essentially **a skillful translator**, the consumer should never have the experience of being lost in a foreign land. The statistician must be fluent in the language of the consumer or ... be willing to learn.”

Defining “Right” Problem



- Often the most critical and valuable step in collaboration
 - Avoid errors of the “third kind”- a sophisticated solution to the wrong question/problem

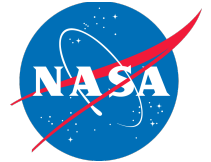
“Far better an approximate answer to the right question, which is often vague, than the exact answer to the wrong question, which can always be made precise.”

“An approximate answer to the right question is worth a great deal more than a precise answer to the wrong question.”

John Tukey

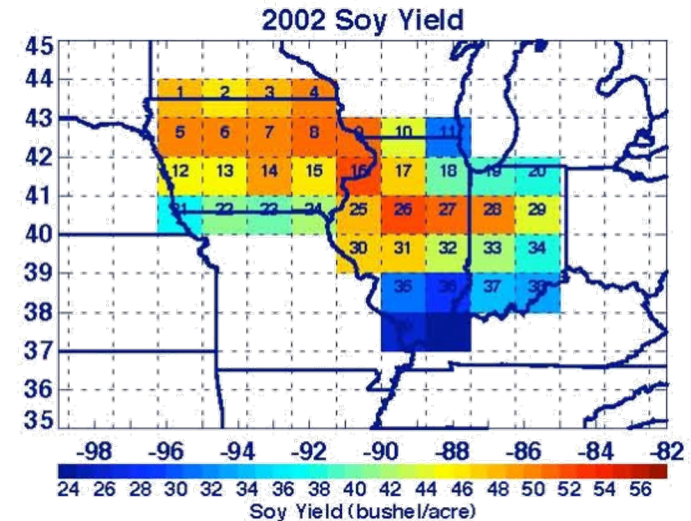
- Team members may assume that they know the “right” problem
- To obtain shared common goals, the problem definition along with the success or exit criteria are intentionally, mutually agreed upon by team

Atmospheric Measurement Application to Improve Soy Bean Production



Background

- Utilize NASA satellite data and models for other national, societal application.
- Benefit soybean crop production in the US



Problem Definition Refinement

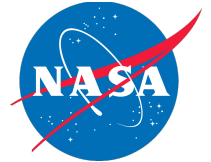
Original Question:

How do we correlate ground-based measurements of ozone with satellite measurements of residual ozone?

Final, Better Question:

How do we use satellite measurements to benefit agricultural production of soybeans?

Start with Fundamental Questions



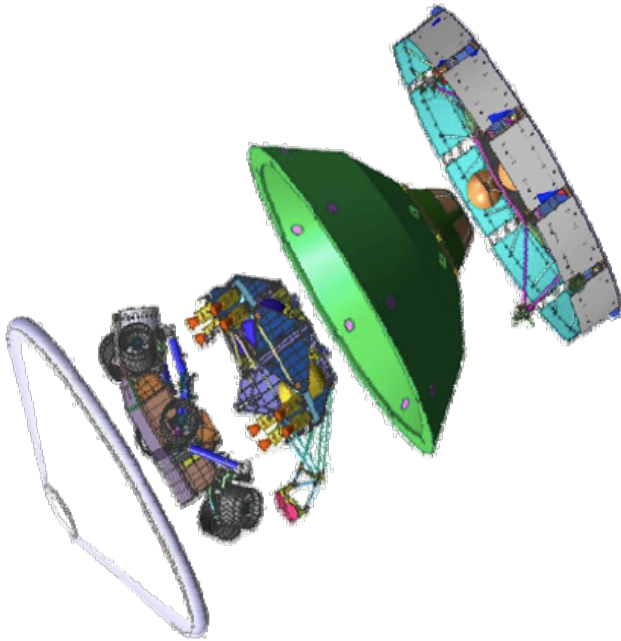
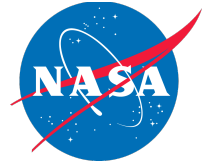
- Heilmeier questions were used as a preflight checklist for successfully launching a research project “**to curb and clarify both the enthusiasm of the researchers and to evaluate the resource demands of the project managers**”
- **What are the precise objectives?**
 - What are we seeking to learn?
 - What are the quantifiable, detectable, measurable objectives?
 - What is the impact if we are successful?

Defines a potential methodological framework, factors, and responses

- **How well do we need to know the answers?**
 - How much risk are we willing to accept in being wrong?
 - What are the consequences if we are wrong?

Defines sample size, power, and scale/volume of data required

Mars Atmospheric Entry

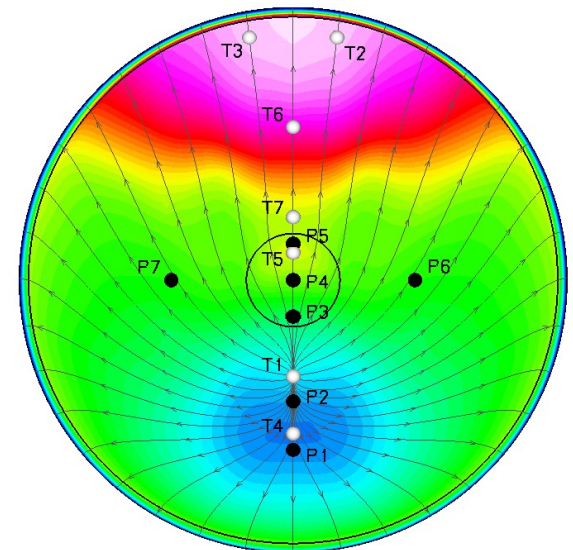


Background

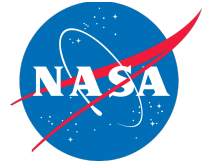
Develop instrumentation and mathematical models to measure the trajectory during entry into the Martian atmosphere

Lessons Learned

- Team formation and mutual goals
- Mutual Respect and Trust
- Collaboration influences Problem Formulation



Statistician's View of their Role



Required for Effective
Statistical Collaboration

**Subject Matter
Expert(s)**

Active

Passive

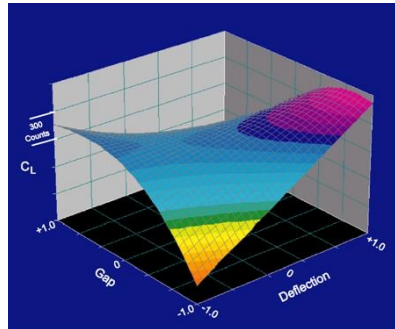
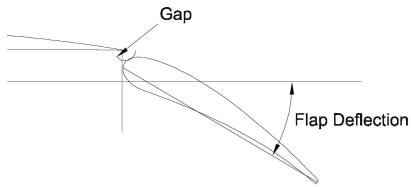
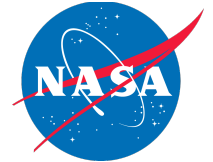
Statistician as Helper	Statistician as Collaborator
	Statistician as Director

Passive

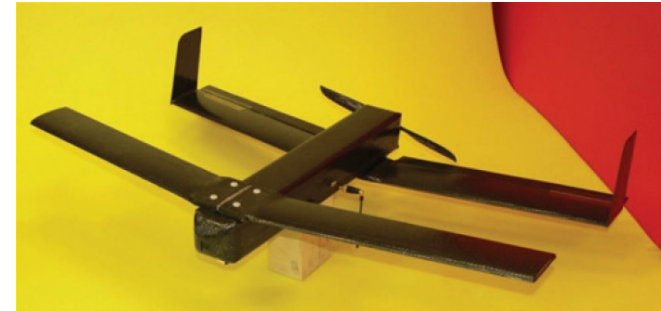
Active

Statistician

Aeroscience Research



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English, et al. (2012), "An Efficient Split-Plot Approach for Modeling Nonlinear Aerodynamic Effects," *Quality Engineering*, 24: 522-530

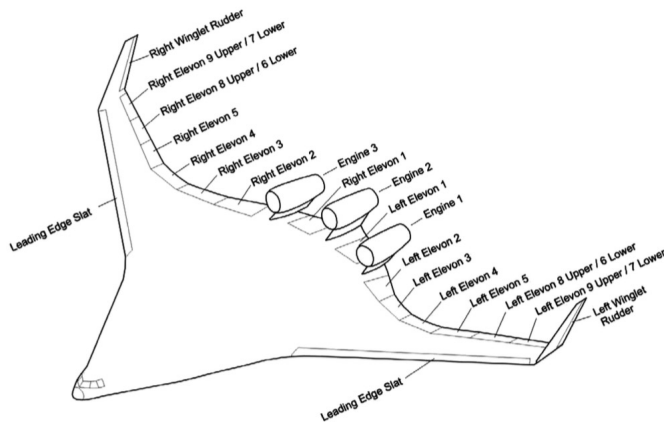


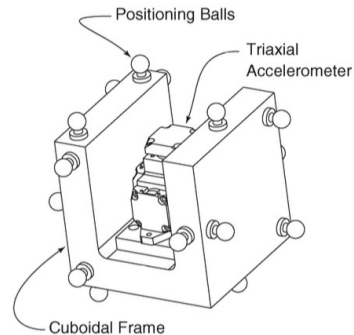
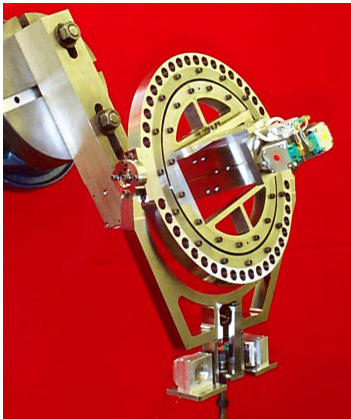
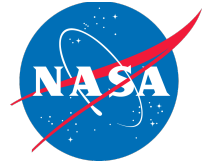
Fig. 2 BWB configuration control surfaces.

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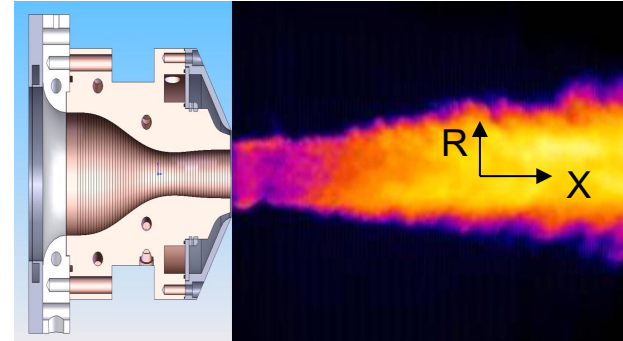


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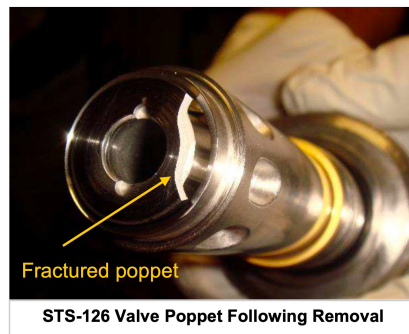
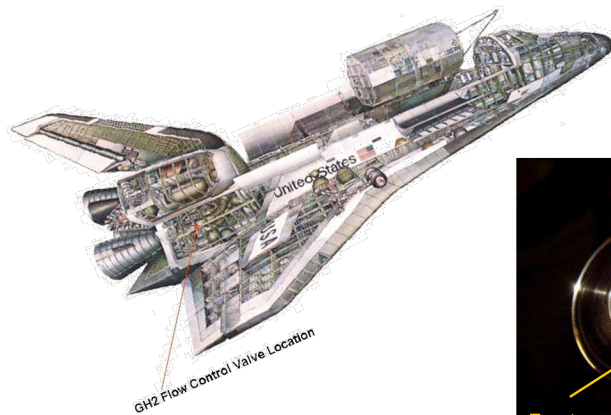
Test and Evaluation



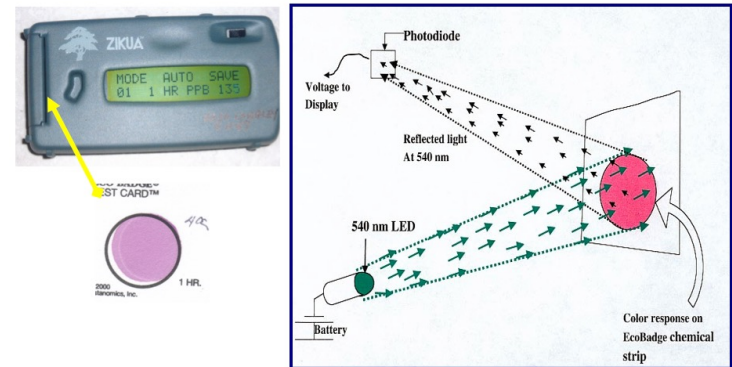
Parker, et al. (2001), "A Single-Vector Force Calibration Method Featuring the Modern Design of Experiments," AIAA 2001-0170



Silvestrini and Parker (2012), "Aerospace Research through Statistical Engineering," Quality Engineering

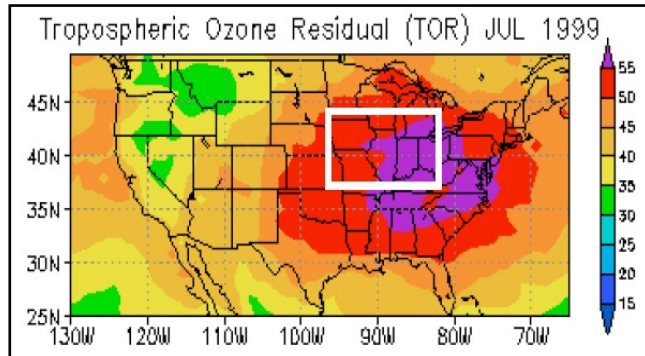
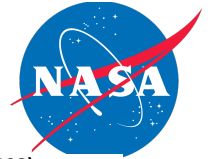


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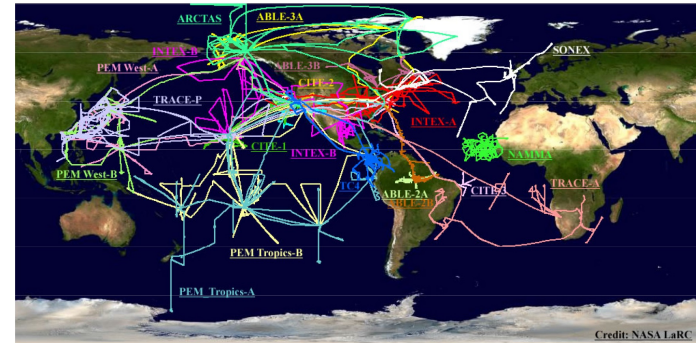
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Atmospheric Sciences

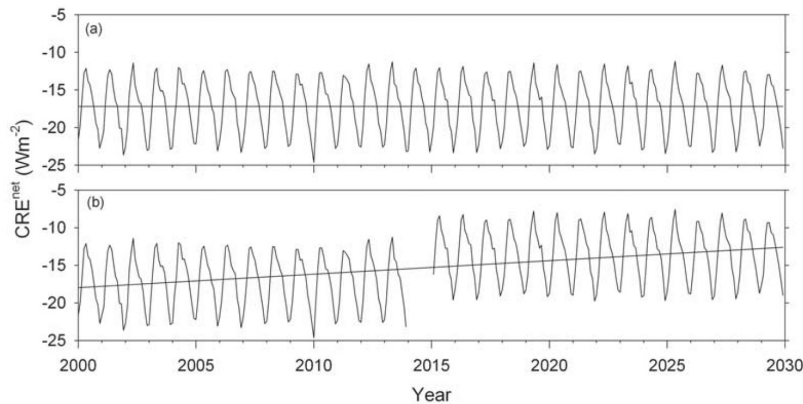


Fishman, et al. (2006), "An Investigation of Widespread Ozone Damage to the Soybean Crop in the Upper Midwest Determined from Ground-Based and Satellite Measurements," *Atmospheric Environment*, 44, pp. 2248-2256.

NASA Tropospheric Airborne Campaigns (1983 – 2008)

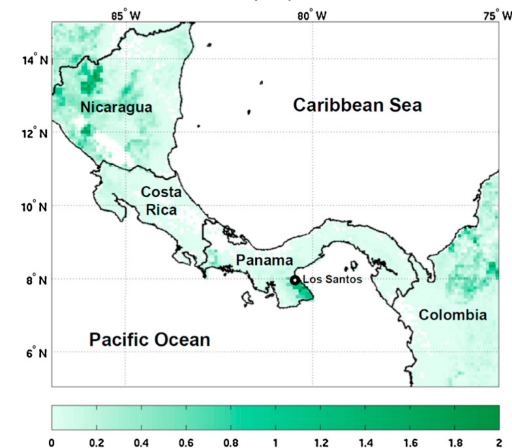


Kleb, et al. (2008), "Creating Airborne ESDR Products for Global and Regional Model Assessment," *American Geophysical Union Annual Conference*.



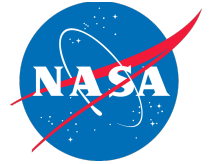
Loeb, et al. (2009), "Impact of Data Gaps on Satellite Broadband Radiation Records," *Journal of Geophysical Research*, 114.

a Maize Production (MT)



Ruane, et al. (2013), "Climate change impact uncertainties for maize in Panama: Farm information, climate projections, and yield sensitivities," *Agricultural and Forest Meteorology*, 170, 132-145.

Concluding Remarks



- **Collaboration is an essential skill** for every discipline expert
- **Embrace the motivation to collaborate**
- Everyone can become a **better collaborator** through
 - Experience, mentoring, and observation (**Art**)
 - Methodological Research (**Science**)



Even if you possess a mastery of powerful statistical tools, you may never get to open your toolbox and influence a project without being an effective collaborator