Statistical Collaboration at NASA

The Art and the Science

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Statistical Consulting (STAT 938) Guest Lecture

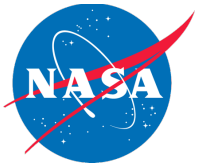
NASA Langley Research Center

- **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**

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.**

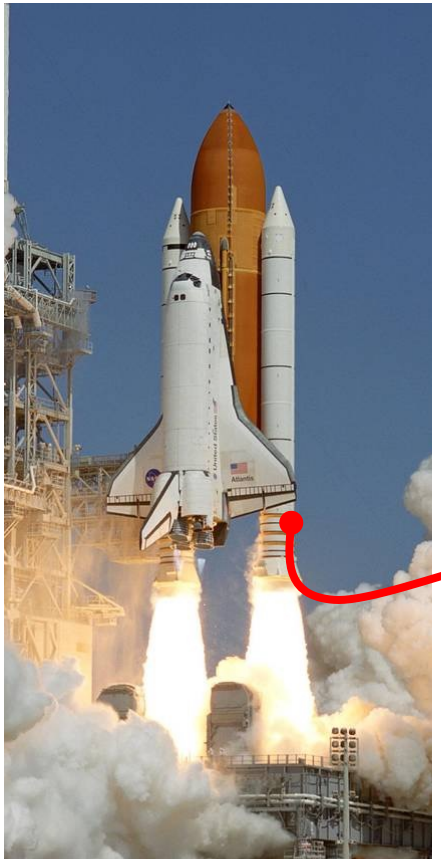
<u>A few "radical" statistical concepts</u>

- **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

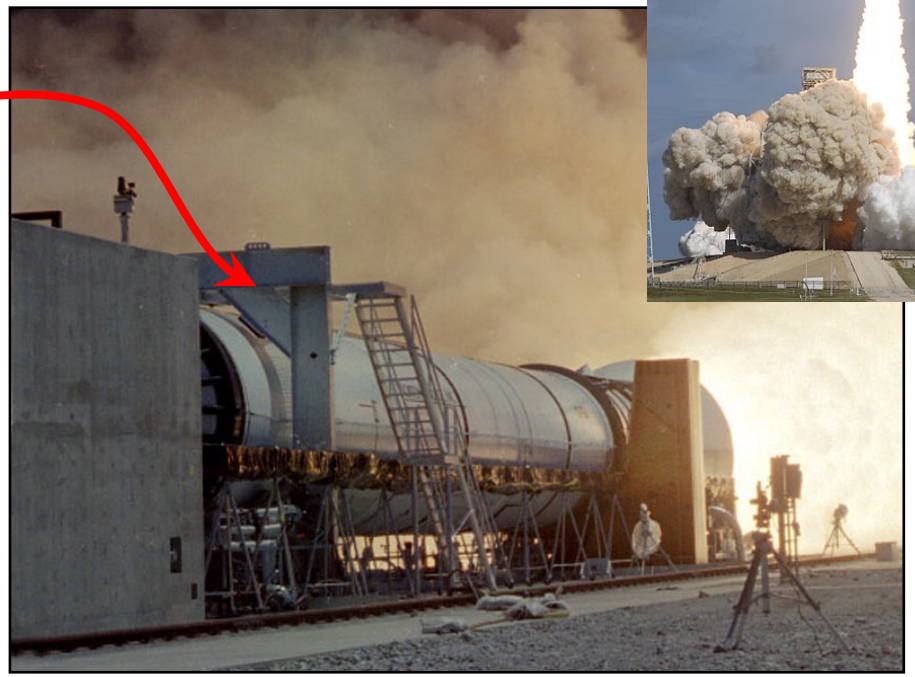
Space Launch System Development

Shuttle

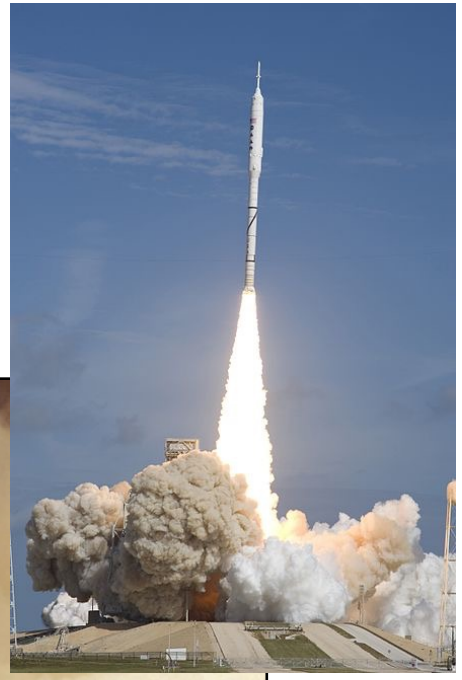


Ares I

Full-Scale Static Firing



Flight Test



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

Anderson-Cook, Lu, Parker (2018) "Effective interdisciplinary collaboration between statisticians and other subject matter experts," *Quality Engineering*

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."

Boroto & Zahn (1989) "Promoting Statistics: On Becoming Valued and Utilized," *The American Statistician*

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**

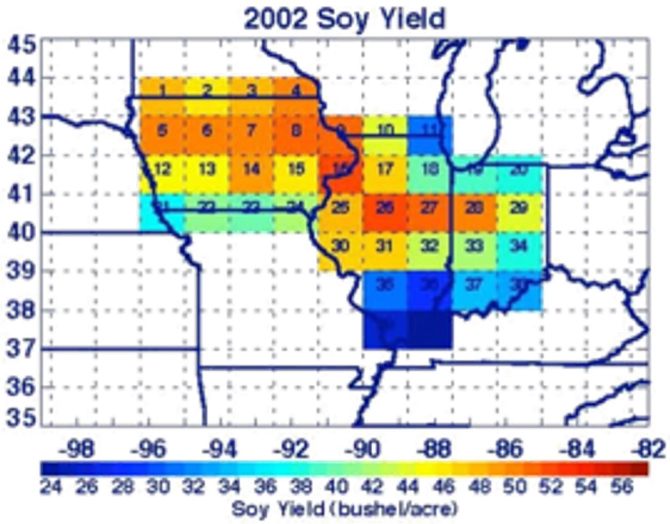
"Far better an approximate answer to the right question, which is often vague, than the exact answer to the wrong question, which can always be made precise."

"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

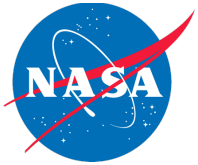
Original Question:

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?**

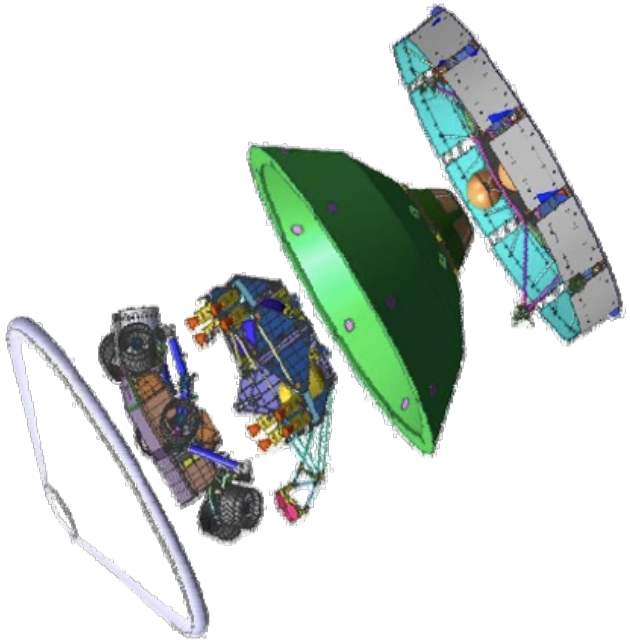
Defines a potential methodological framework, factors, and responses

- **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

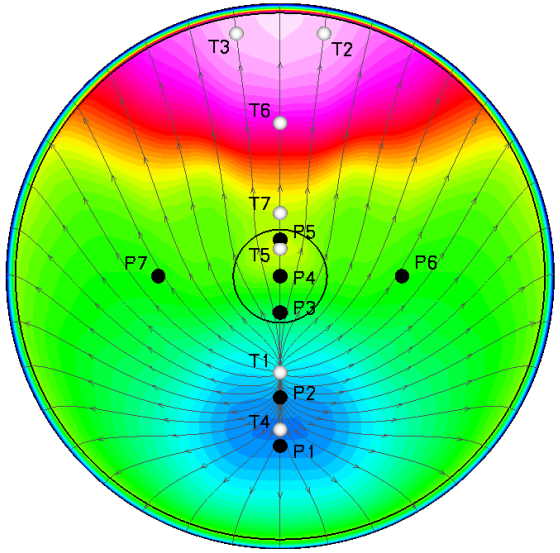
Shapiro (1994) "George H. Heilmeier," *IEEE Spectrum*

Mars Atmospheric Entry



Background

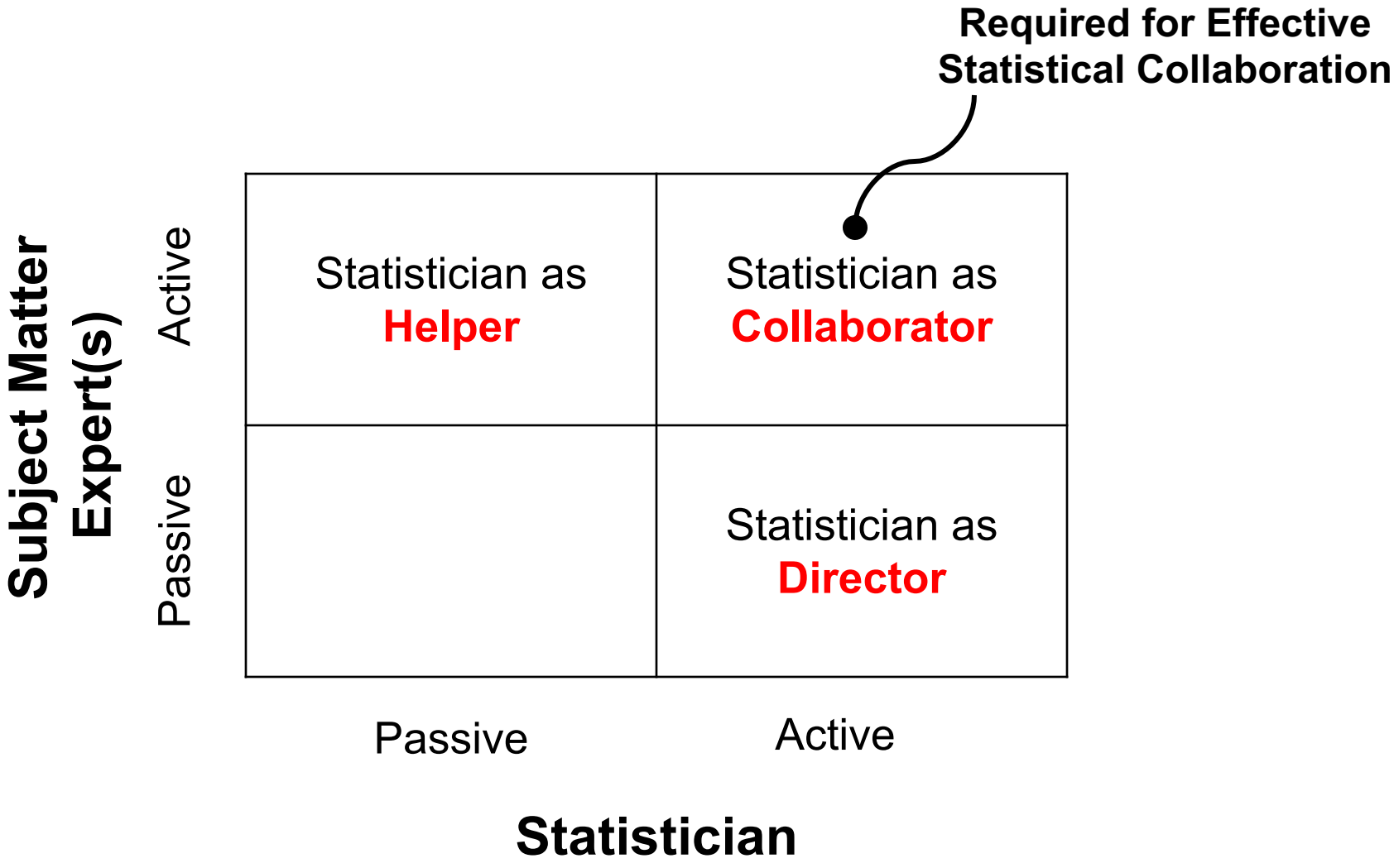
Develop instrumentation and mathematical models to measure the trajectory during entry into the Martian atmosphere



Lessons Learned

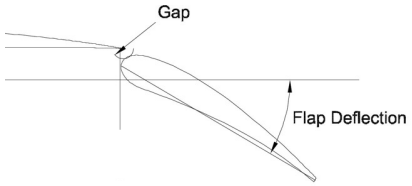
- **Team formation and mutual goals**
- **Mutual Respect and Trust**
- **Collaboration influences Problem Formulation**

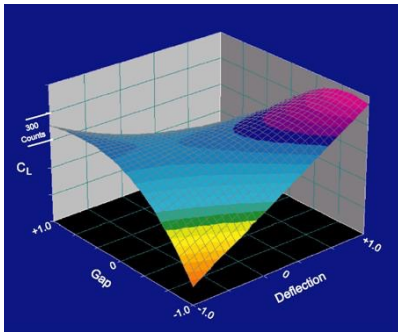
Statistician's View of their Role



Hunter, W.G. (1981) "The Practice of Statistics: The Real World Is an Idea Whose Time Has Come," *The American Statistician*

Aeroscience Research





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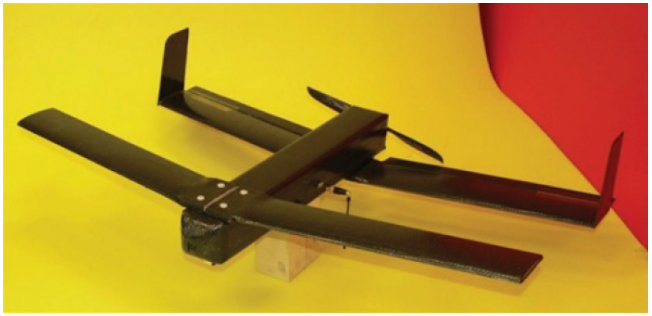

English, et al. (2012), "An Efficient Split-Plot Approach for Modeling Nonlinear Aerodynamic Effects," *Quality Engineering*, 24: 522-530

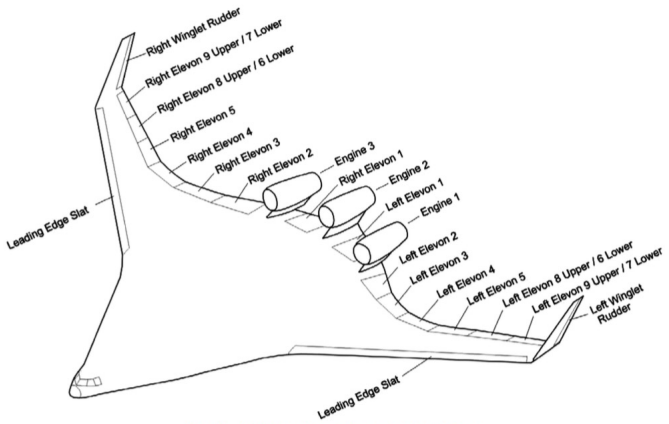

Fig. 2 BWB configuration control surfaces.

Landman, et al. (2007), "Response Surface Methods for Efficient Complex Aircraft Configuration Aerodynamic Characterization," *Journal of Aircraft*, 44, (4)

Overmeyer, et al. (2015), "Case Studies for the Statistical Design of Experiments Applied to Powered Rotor Wind Tunnel Tests," AIAA 2015-2713

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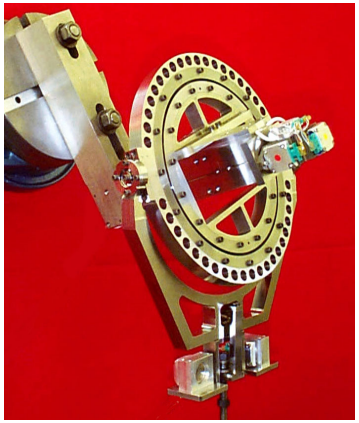
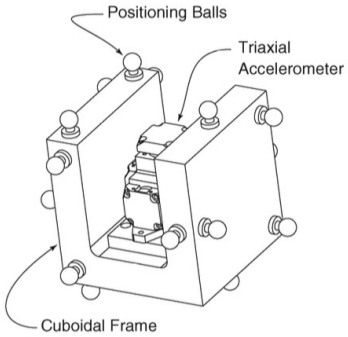
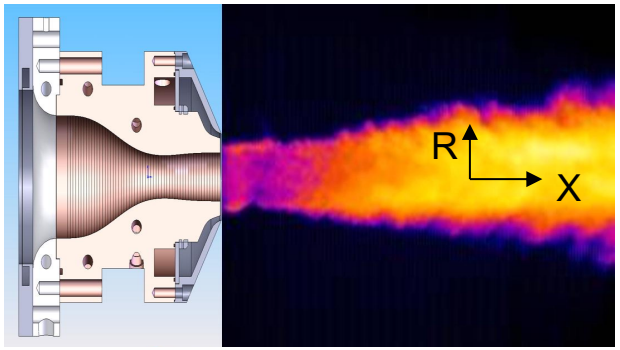




Parker, et al. (2001), "A Single-Vector Force Calibration Method Featuring the Modern Design of Experiments," AIAA 2001-0170



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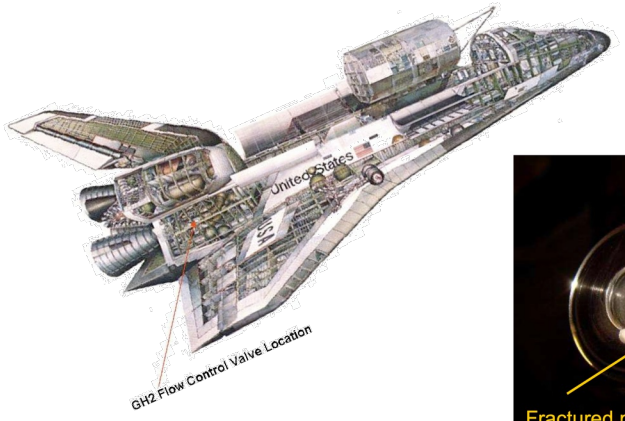
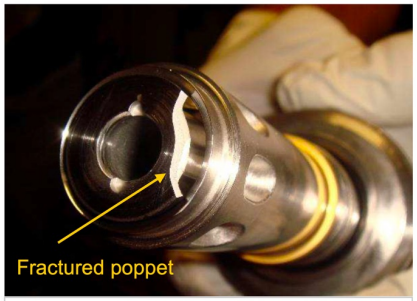
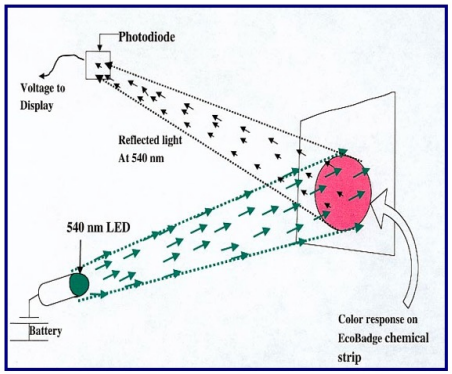




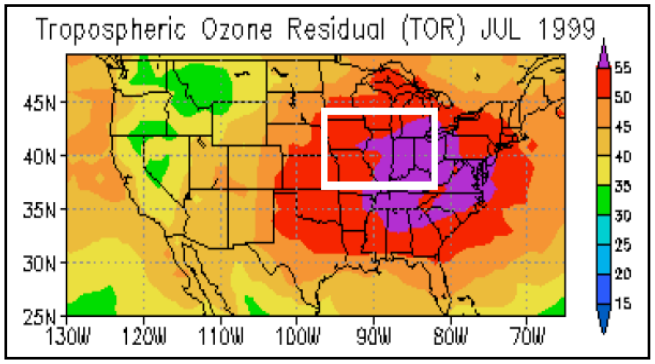
STS-126 Valve Poppet Following Removal

(2009), "Gaseous Hydrogen Flow Control Valves," *NASA Fact Sheet (www.nasa.gov/pdf/313985main_Flow_Valve_Fact.pdf)*



Pippin, et al. (2007), "Improvements to the Passive Ozone Measurement System Used by GLOBE Schools," *American Geophysical Union Annual Conference.*

Atmospheric Sciences



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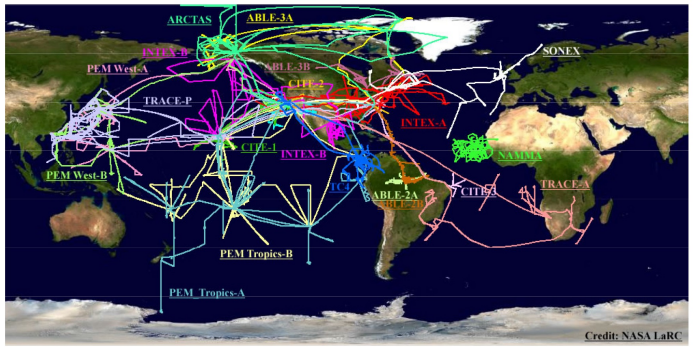
NASA Tropospheric Airborne Campaigns (1983 – 2008)



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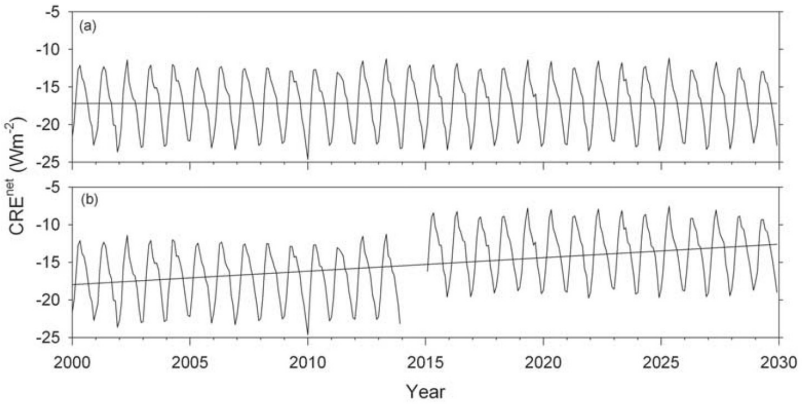

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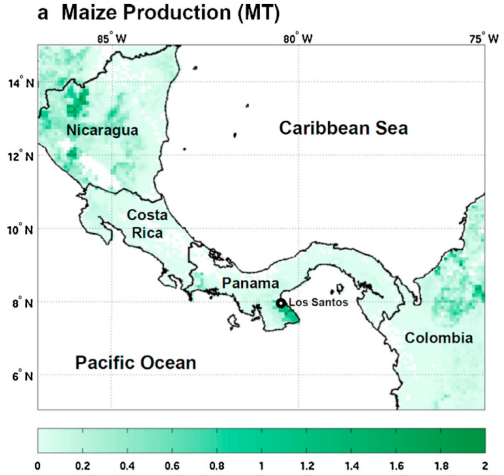

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Concluding Remarks

- **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