



AIAA Aviation

Overview of Uncertainty Analysis Activities at NASA Glenn's Aeropropulsion Facilities

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June 24, 2015



Overview

- Background
- Objectives
- Approach
 - Uncertainty Classification
 - Defining elementary errors
 - Instrumentation
 - Random
 - Systematic
 - Monte Carlo Simulation



Why? And Why Now?

- As technology progresses, the changes on the variables of interest get smaller. Researchers need to know that the change of interest (for example, 1% increase in thermodynamic efficiency) are measurable and not within the uncertainty of the measurement.
- The uncertainty of the operating condition of the facility directly impacts the uncertainty of the measured variable.



Objectives

- Develop Measurement Uncertainty Analysis Knowledge in the GRC Testing Division
- Develop a tool to analyze Instrumentation Level uncertainties in all facilities
- Determine Facility characteristic uncertainties for all aeropropulsion test facilities at GRC
- Train all GRC Testing Division Staff in the uncertainty analysis process

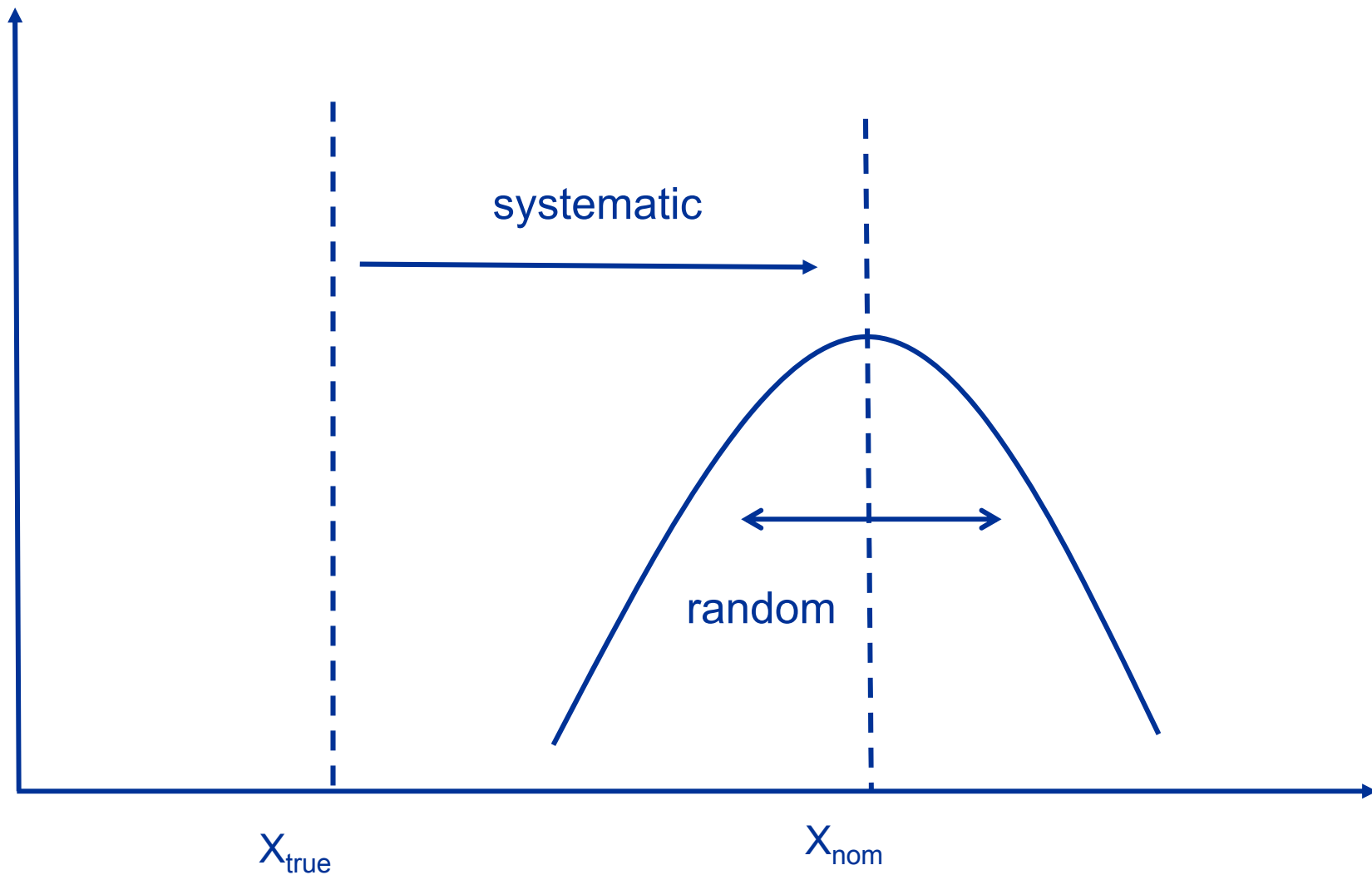


Approach

- Determine the variable(s) of interest
- Determine the uncertainty sources
- Determine a usable data set
- Define a model
- Analyze



Random Vs. Systematic



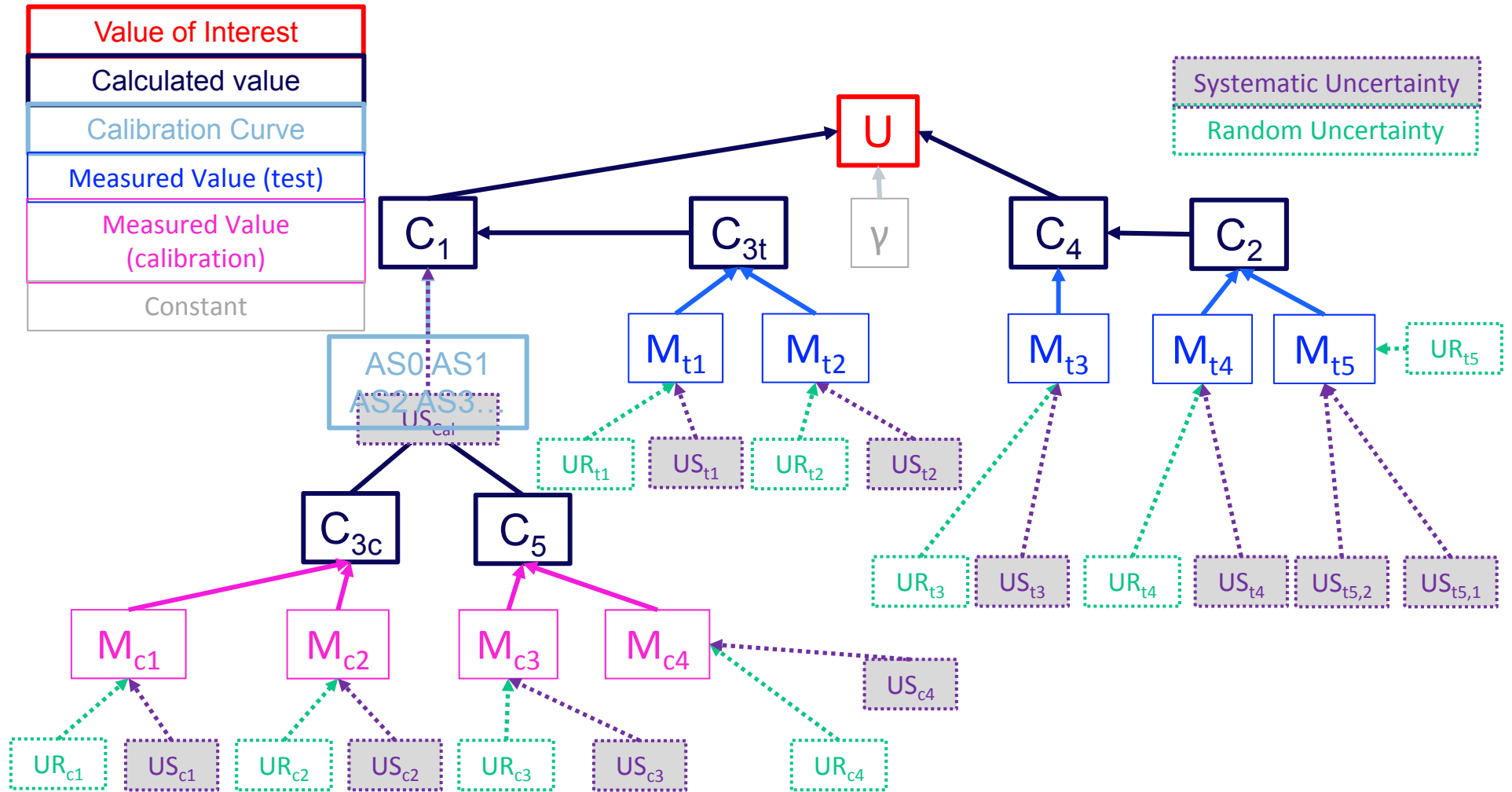


Uncertainty Type Classification

- ISO GUM:
 - Type A: evaluate by statistical analysis of observations (calculated with a standard deviation)
 - Type B: evaluate by other means (based on calibration certificates, past experience, etc.)
 - No distinction between “random” and “systematic” to avoid ambiguity
- Distinguishing between Random and Systematic is useful in determining changes that will improve facility uncertainty.
 - comparison with CFD results cares more about systematic uncertainty
 - tests looking at the effect of model changes will care more about random uncertainty.

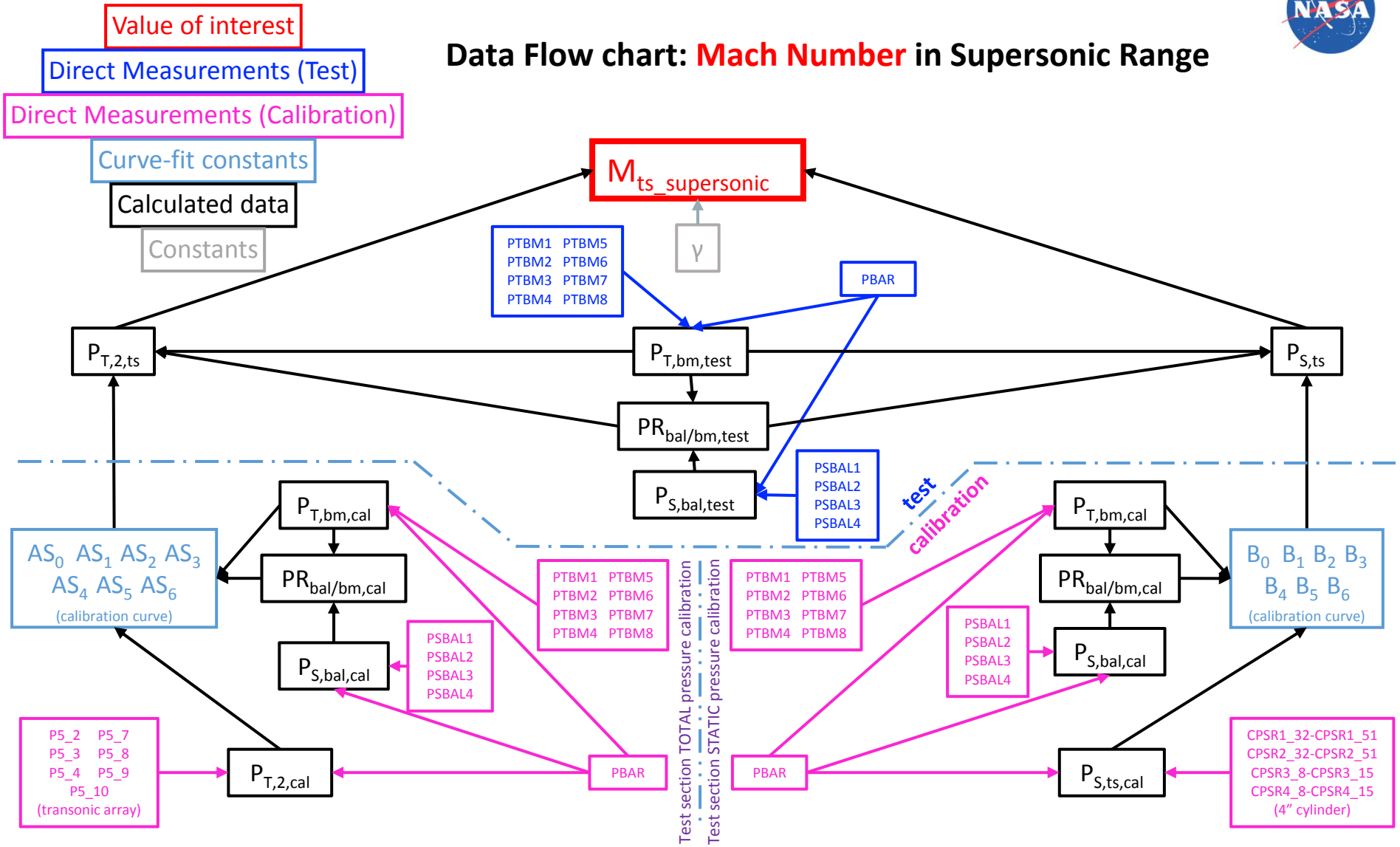


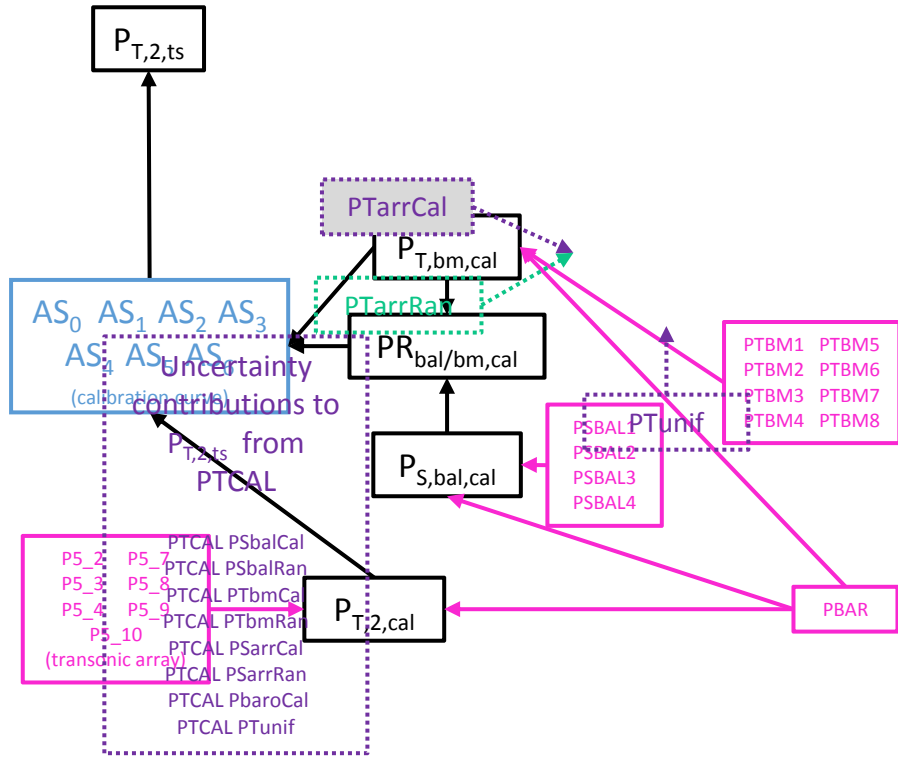
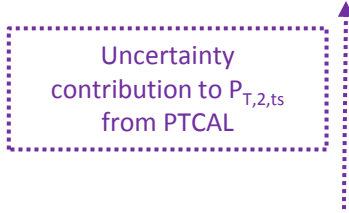
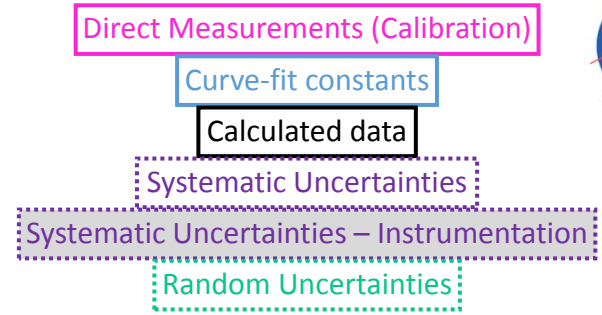
Uncertainty Propagation



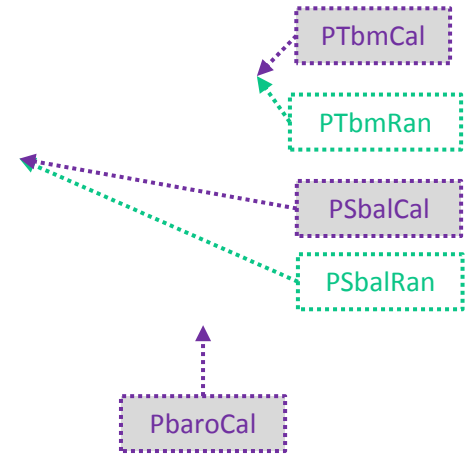


Data Flow chart: Mach Number in Supersonic Range





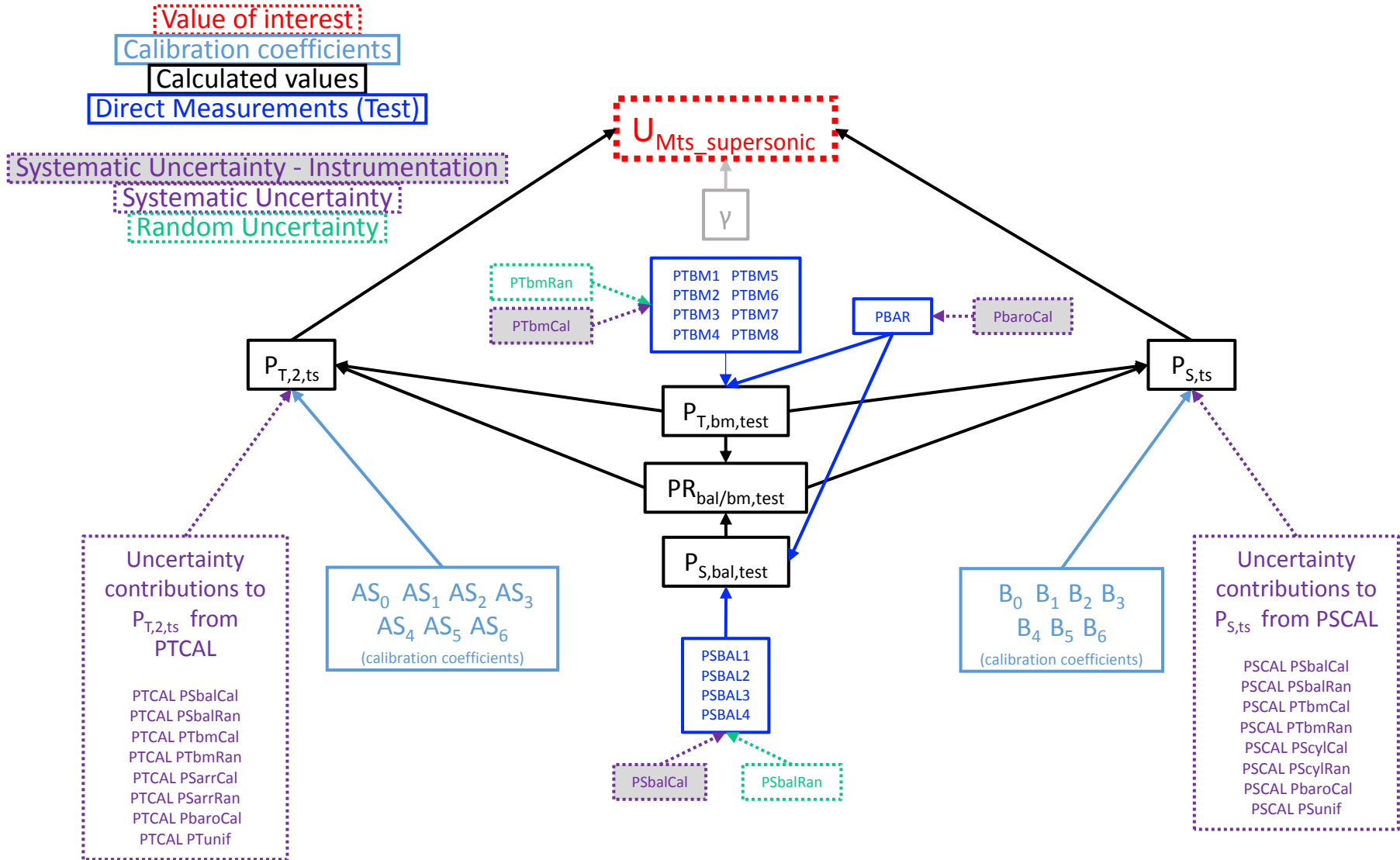
Test section TOTAL pressure calibration



- Note: Once calibration simulation is complete, both random and systematic standard uncertainties are “fossilized” and represented as systematic standard uncertainties for test simulation



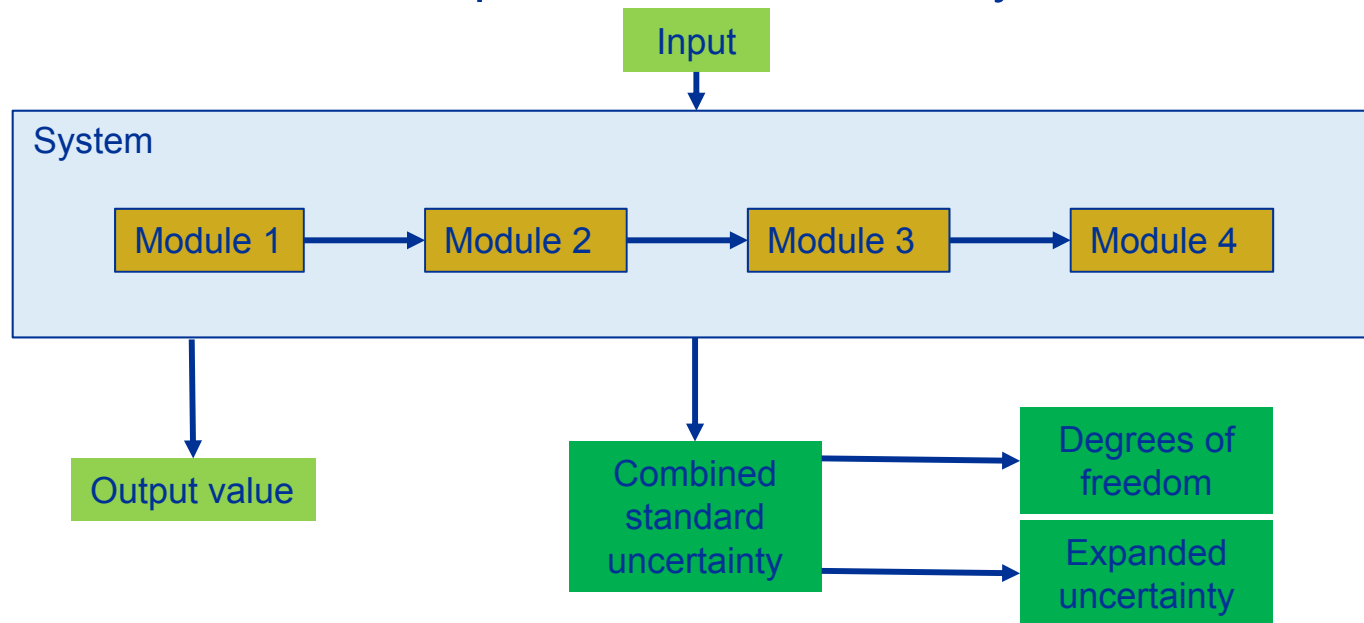
Uncertainty Propagation chart: Mach Number in Supersonic Range





Elemental Errors: Instrumentation Uncertainties

- Spreadsheet based
- ISO Guide to the Expression of Uncertainty in Measurement (GUM)*



*JCGM 100:2008 Evaluation of Measurement Data – Guide to the Expression of Uncertainty in Measurement



Elemental Errors: Random Uncertainties

- Random deviation about the measured value
- Mean Value:

$$\bar{X} = \frac{1}{N} \sum_{i=1}^N X_i$$

- Standard deviation:

$$\sigma_X = \sqrt{\frac{1}{N-1} \sum_{i=1}^N (X_i - \bar{X})^2}$$

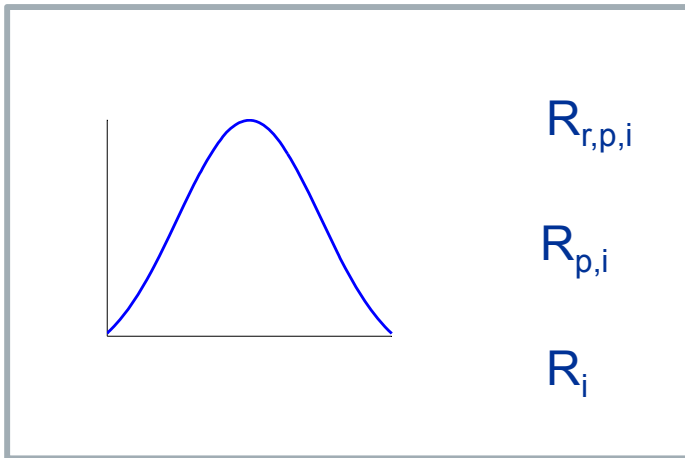


Random number

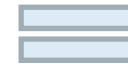
Scaled
by

uncertainty

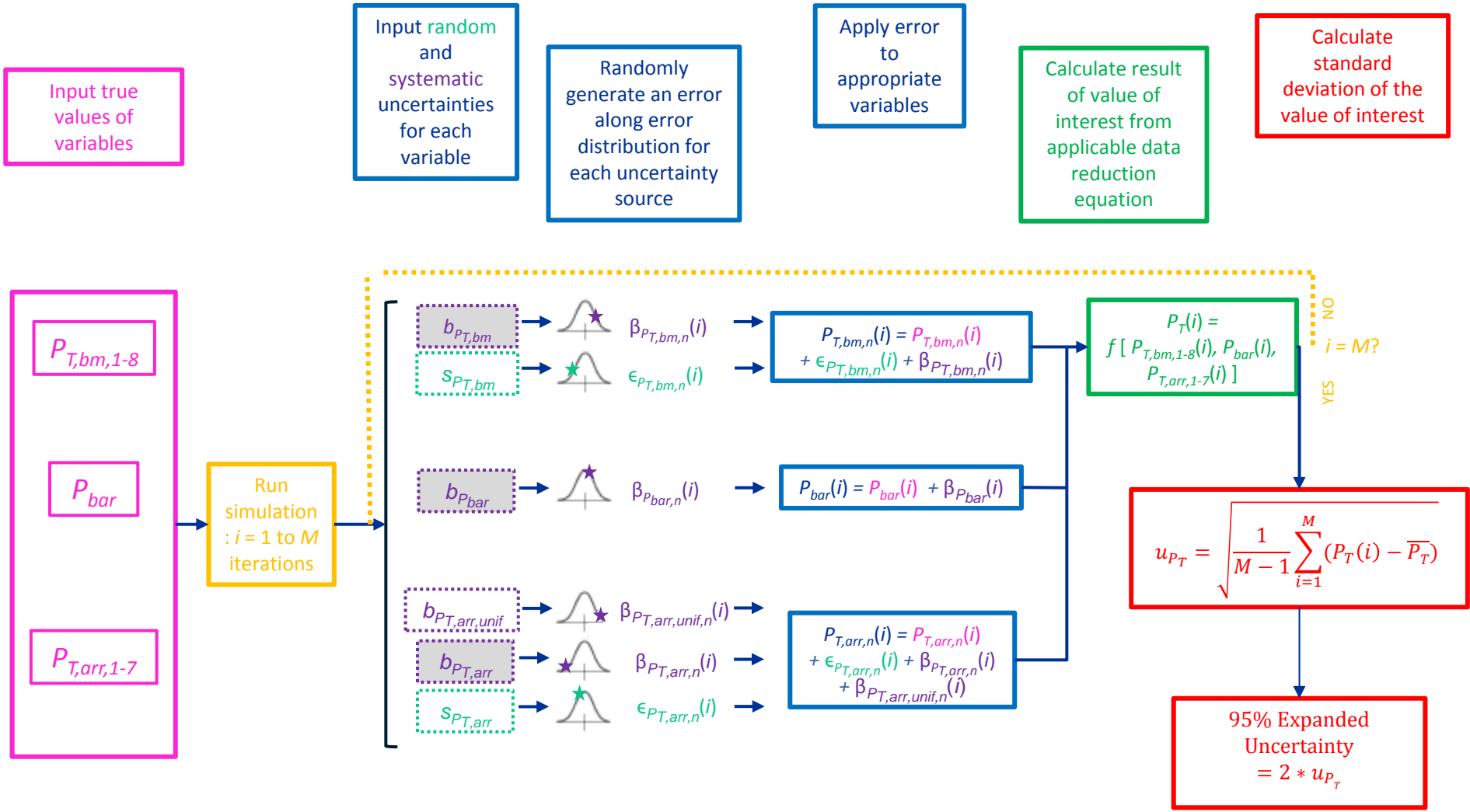
error

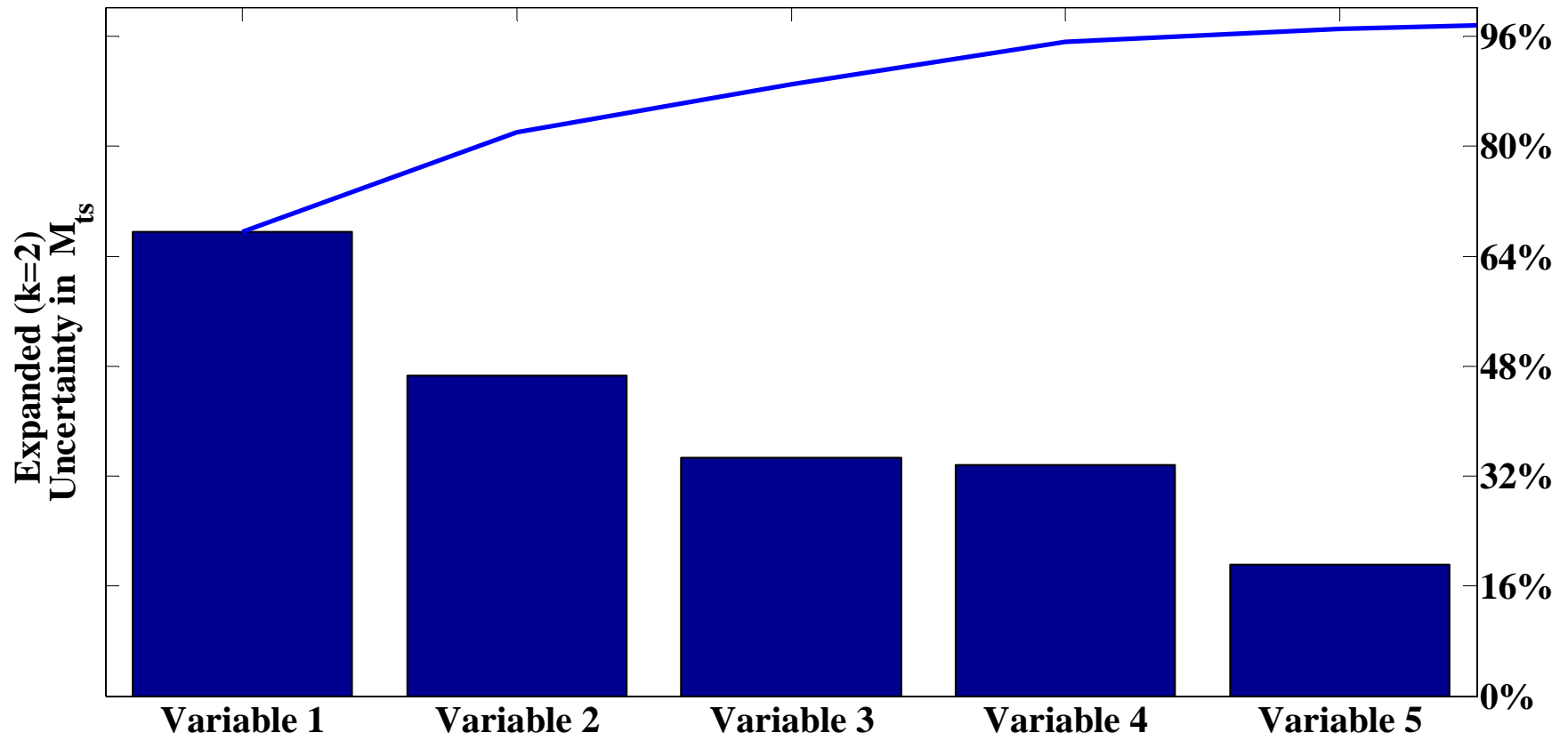


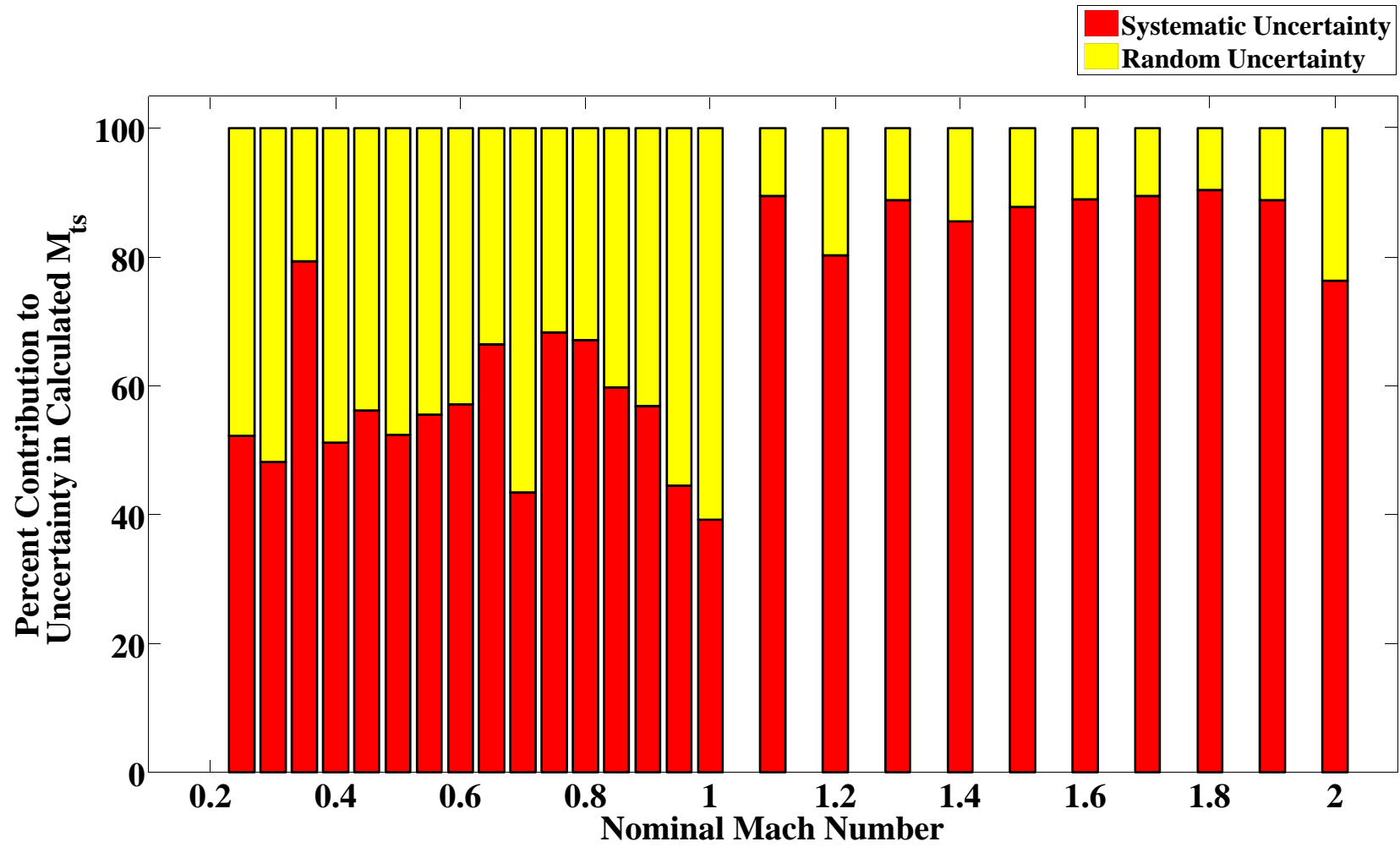
random	s
systematic	b
Correlated systematic	b_c

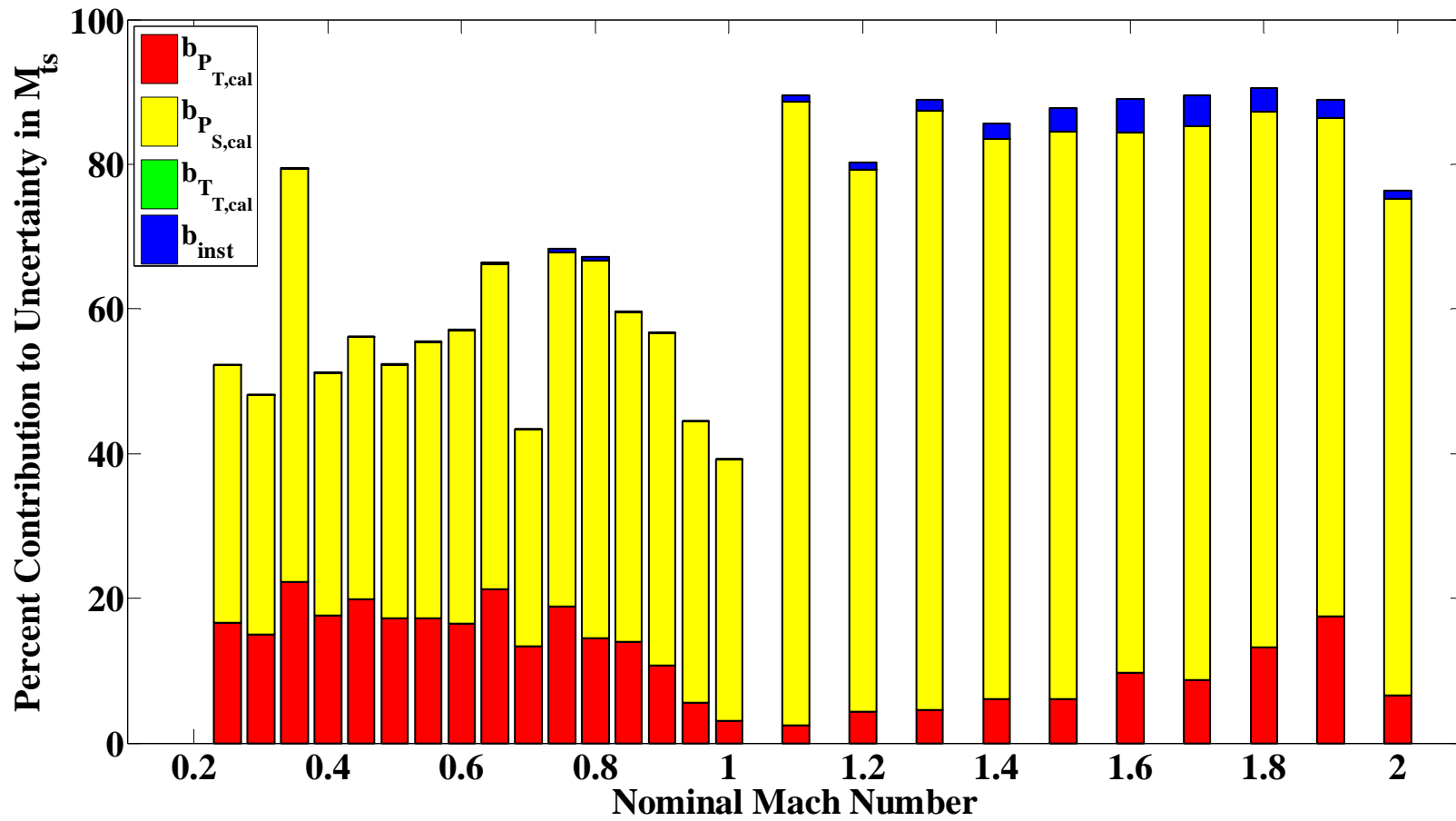


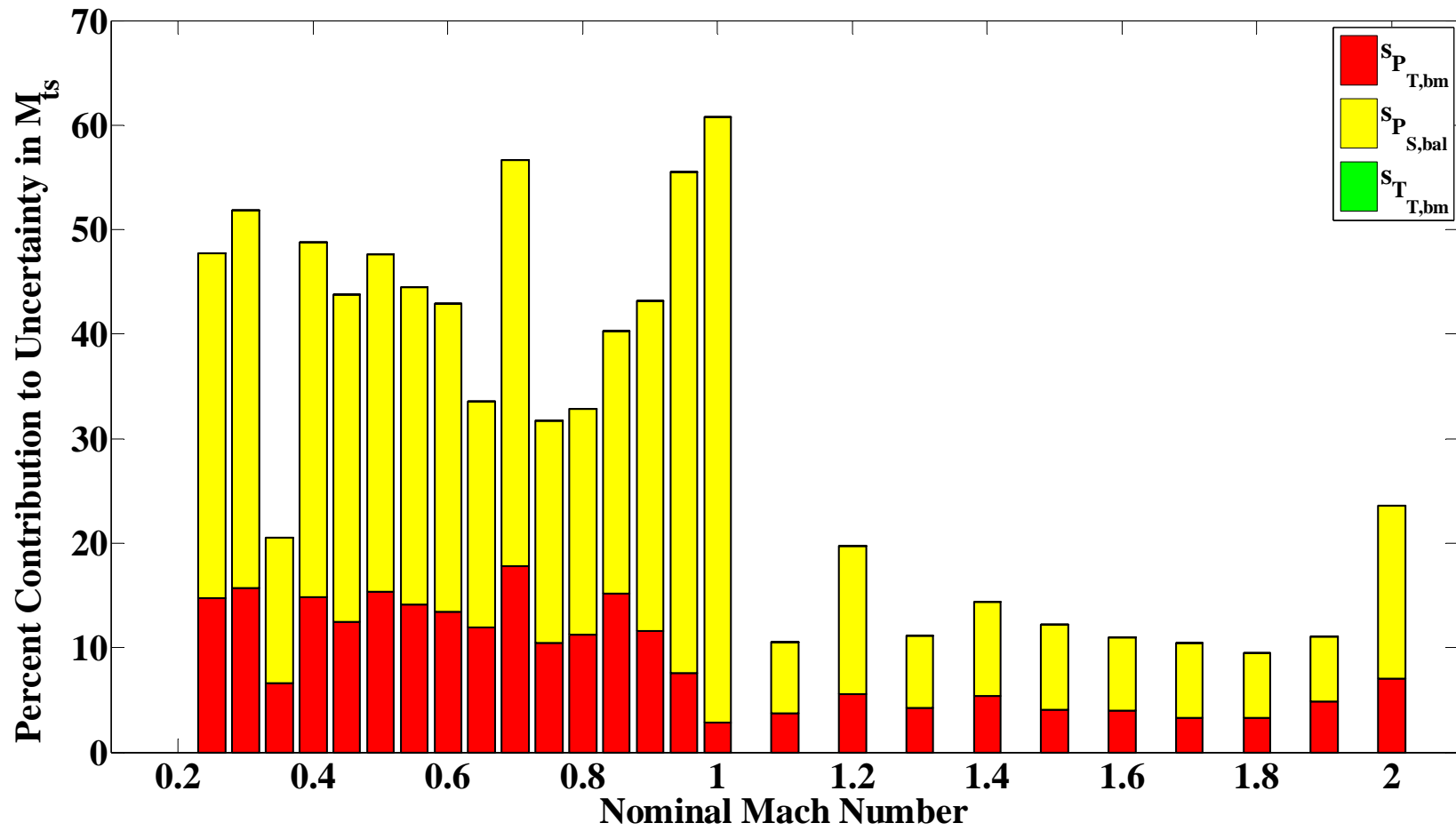
$\epsilon_{r,p,i}$
$\beta_{r,p,i}$
$\beta_{c,r,p,i}$













Determining Potential Improvements

- Quantify the effects of:
 - Modifying calibration process
 - Increasing number of data points available for analysis
 - Improving instrumentation
 - Improving flow quality of facility
 - Modifying run time operations

- Perform cost-benefit analysis for effective facility and data improvement



Conclusions

- Thorough investigations of uncertainties in facilities at GRC underway
- Instrumentation level uncertainties will be easily identified using new spreadsheet tool, “MANTUS”
- Categorizing uncertainties as “random” and “systematic” useful in determining potential areas of improvement
- In-depth uncertainty analysis results and potential improvement scenarios provide keys to understanding how facilities and data can continue to improve