



The Spastic Monkey:

Flight Testing Using Uncorrelated Pilot Inputs

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Aermacchi MB-326M Impala



Credit: NASA Langley Research Center



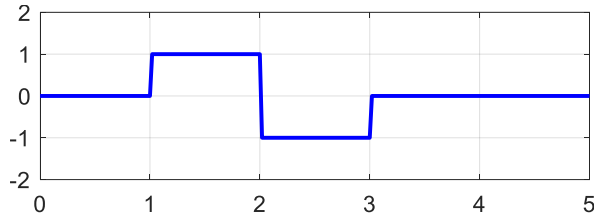
Credit: NASA Langley Research Center

Modeling results can be used to analyze, predict, and control

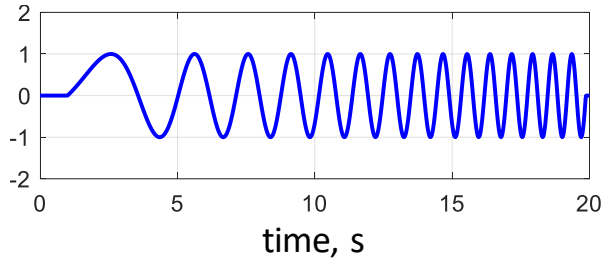
Accurate dynamic modeling results require informative multi-axis data
How can this data be acquired efficiently in piloted flight testing?

Single-input (sequential):

Doublet

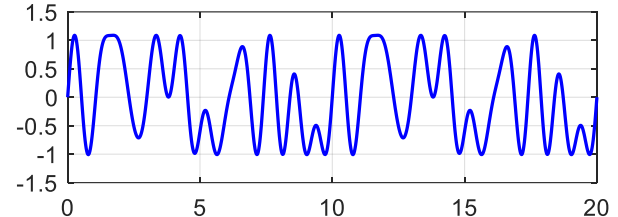


Frequency Sweep

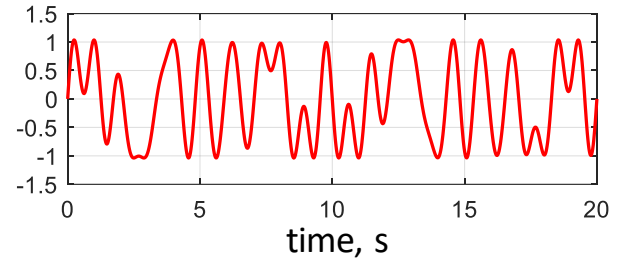


Multiple-input (parallel):

u_1



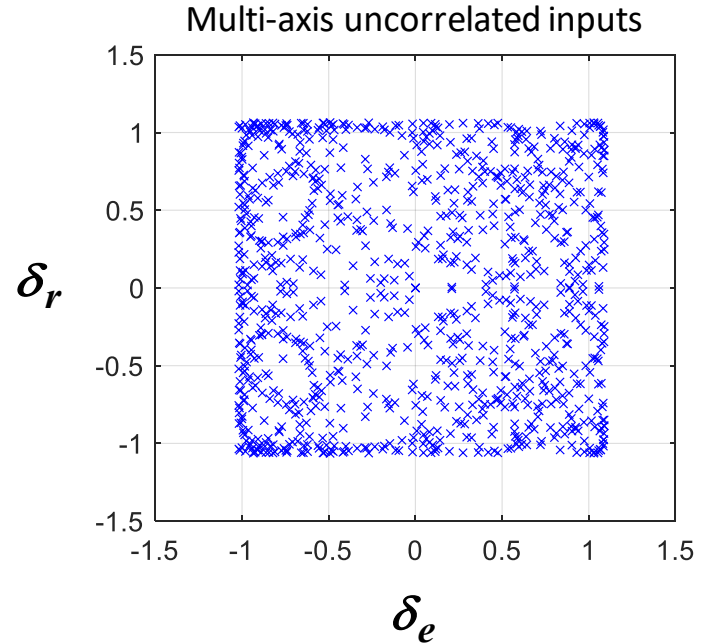
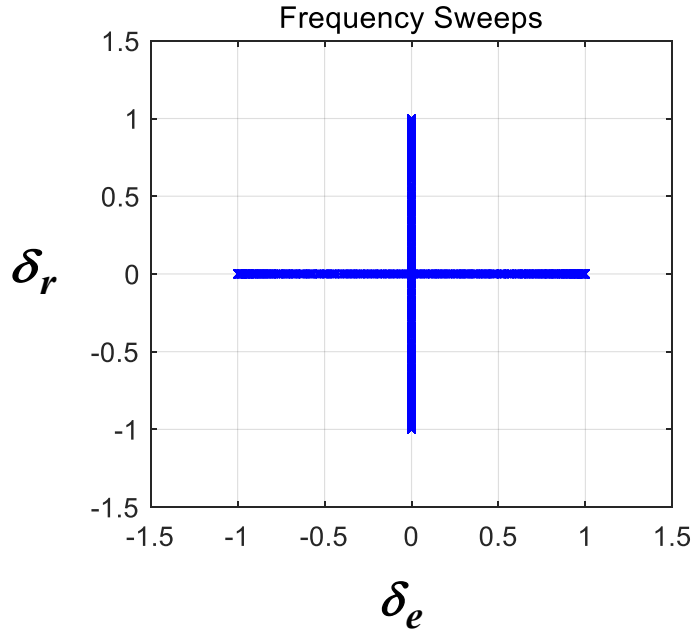
u_2



Advantages of Multiple Inputs Applied Simultaneously:

- Improved flight test efficiency
- More informative multi-axis aircraft dynamic response
- Control interaction effects can be modeled

Control Interaction Effects



Critical when many controls are close to each other or to propulsion



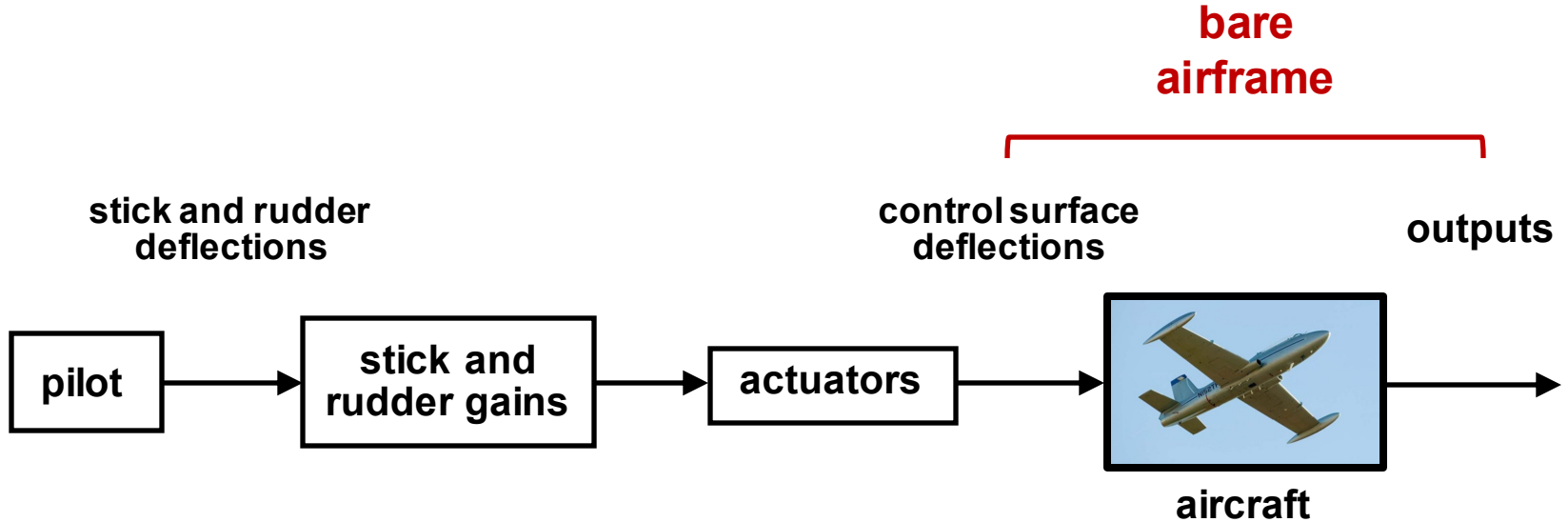
What Makes Flight Test Maneuvers Good?

- Low correlations among explanatory variables
- High signal-to-noise for the responses
- Wideband frequency content for the controls
- Regulated nominal flight condition
- Multi-axis excitation:
 - Flight test efficiency
 - Enhanced dynamic information
 - Control interaction effects

Test pilots can achieve all of these characteristics using Uncorrelated Pilot Inputs (UPI, aka “the spastic monkey”) with little or no training



Stick-to-Surface Control

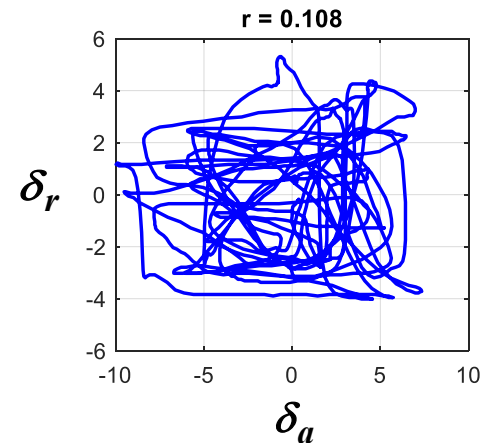
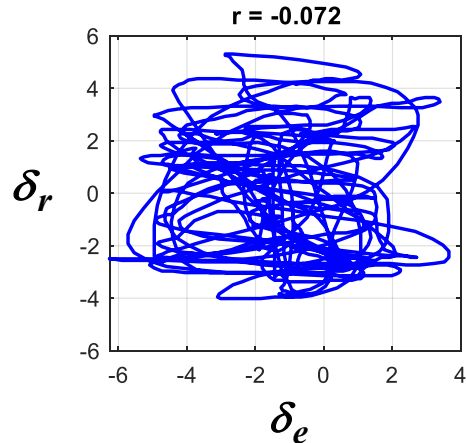
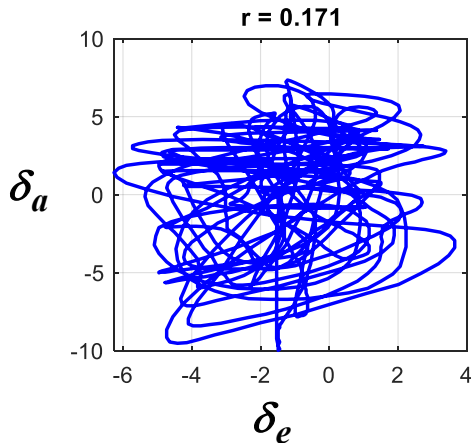


Uncorrelated Pilot Inputs (UPI)

A test pilot can implement uncorrelated multi-axis inputs when the aircraft has no feedback control

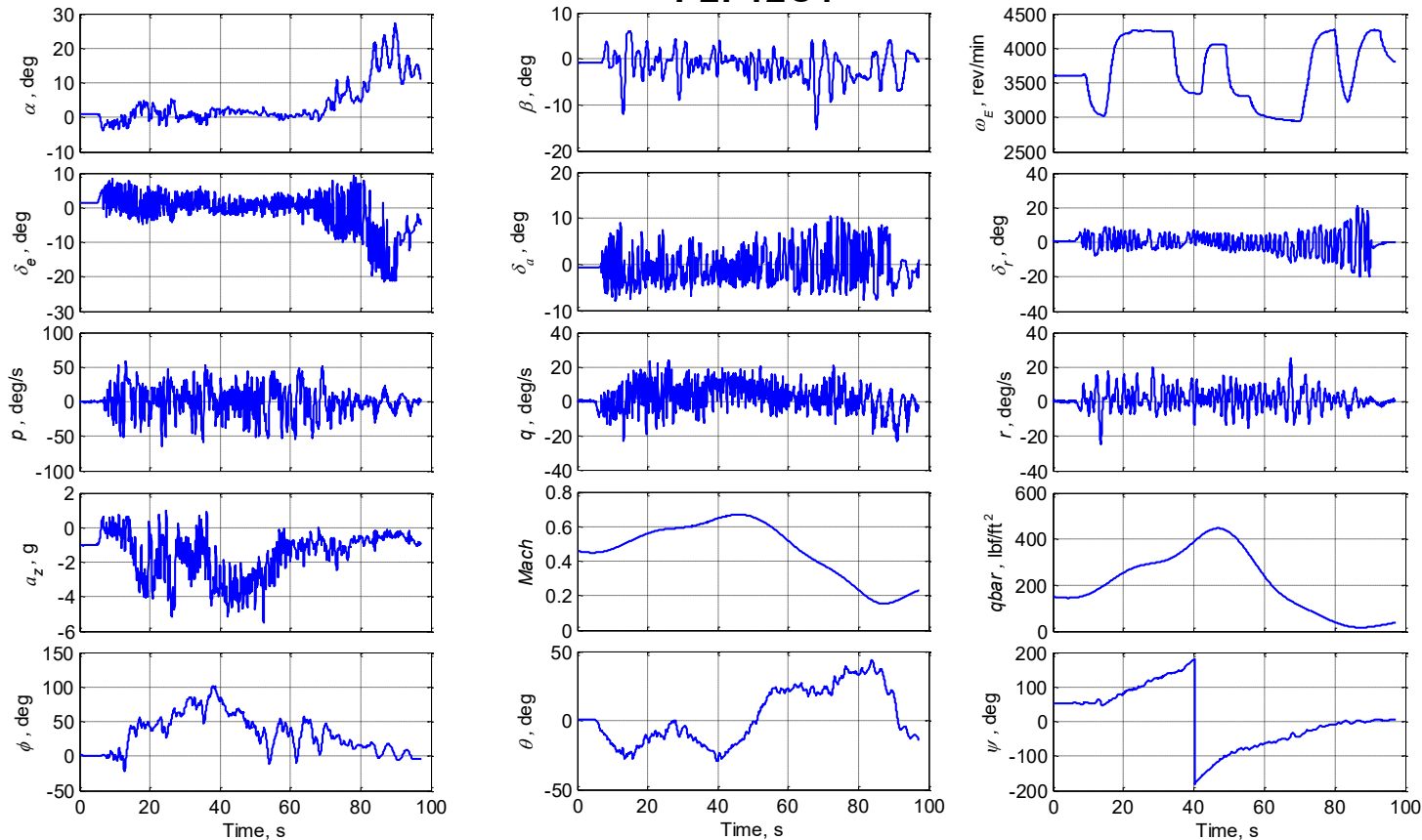
Maneuver length = 27 s

Impala



Global Multi-Axis Maneuver

P2F12C4



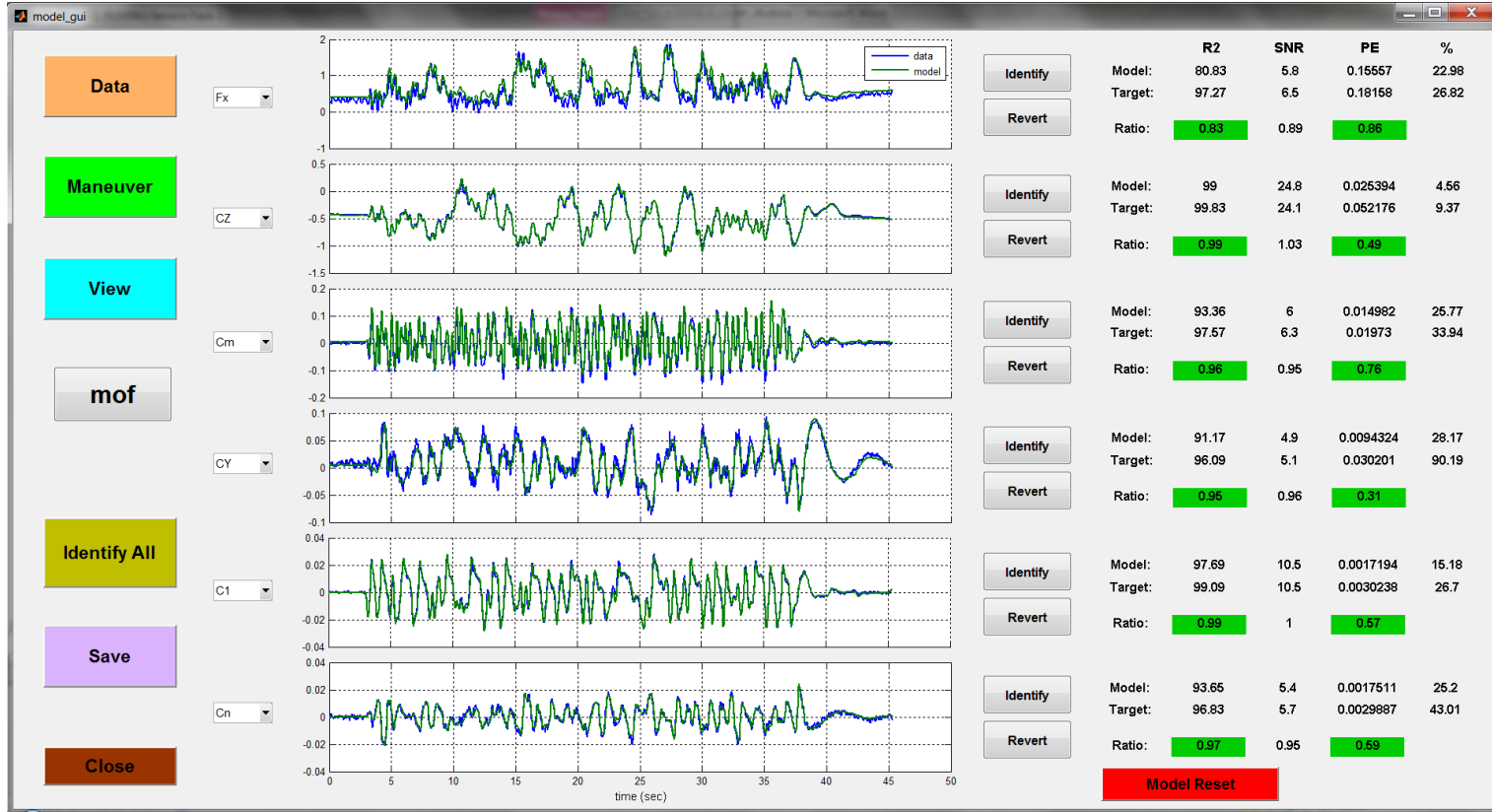


Global Multi-Axis Maneuver

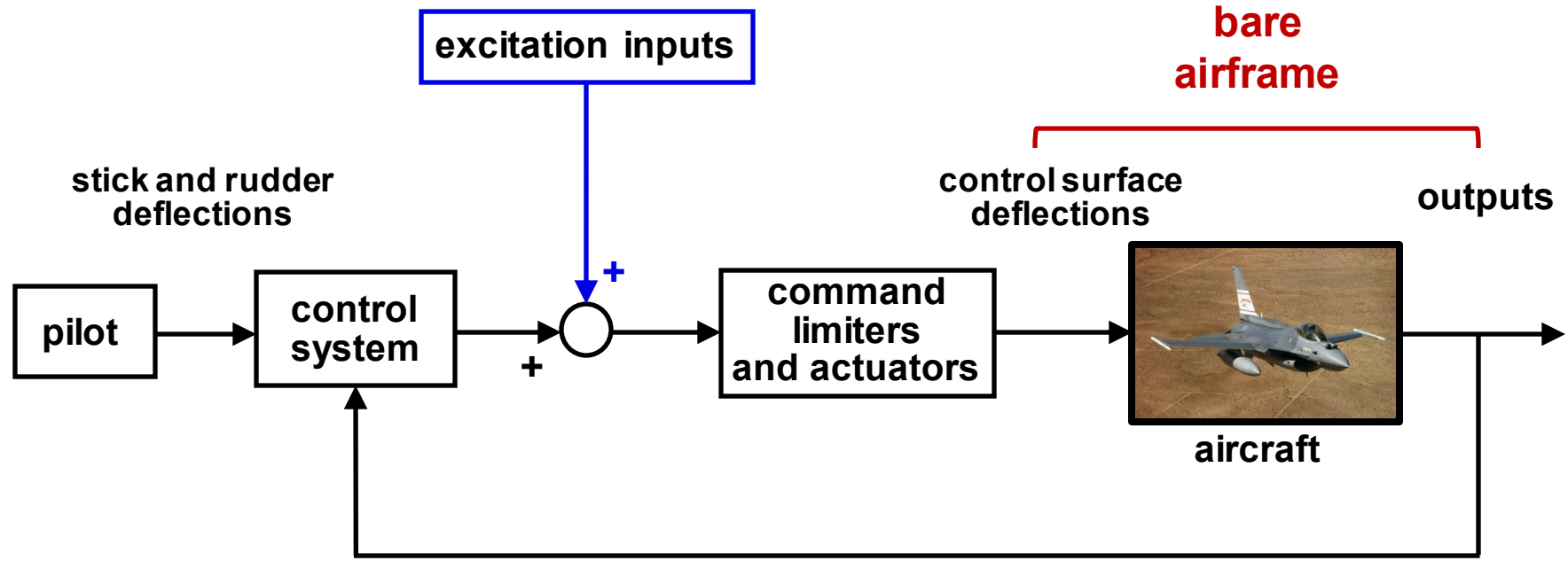




In-Flight Local Prediction from Global Model



Active Feedback Control



With this approach, informative flight data will be obtained regardless of what the pilot or feedback control are doing



Impala Flight Test Results



- Global aerodynamic and propulsion models identified and validated in flight for 3 configurations in a 1-hour flight test:
 - Up and away, flaps up, gear up
 - Approach, flaps half, gear down
 - Landing, flaps full, gear down
- Demonstrated UPI during steady flight conditions, slow approach to stall, and during maneuvers with significant changes in Mach and load factor
- Test pilots were only briefed verbally pre-flight, no simulator training
- Maneuver efficiency and effectiveness validated with prediction cases



Conclusions



- Pilots can use their flying skills to achieve the flight test goal:
Efficiently collect informative multi-axis data for dynamic modeling
- No preflight input design or pilot training to implement input forms
- Benefits of multi-axis inputs can be achieved by a pilot
- Approach can be applied at any flight condition
- Demonstrated with stick-to-surface control, but also applicable to flight testing with active feedback control
- Can be used in conjunction with real-time modeling for efficient flight testing and test pilot training



References



- Brandon, J.M. and Morelli, E.A. “Nonlinear Aerodynamic Modeling From Flight Data Using Advanced Piloted Maneuvers and Fuzzy Logic,” NASA/TM-2012-217778, October 2012.
- Morelli, E.A., Cunningham, K., and Hill, M.A. “Global Aerodynamic Modeling for Stall/Upset Recovery Training Using Efficient Piloted Flight Test Techniques,” AIAA 2013-4976, *AIAA Modeling and Simulation Technologies Conference*, Boston, MA, August 2013.
- Brandon, J.M. and Morelli, E.A. “Real-Time Global Nonlinear Aerodynamic Modeling from Flight Data,” *Journal of Aircraft*, Vol. 53, No. 5, September-October 2016, pp. 1261-1297.
- Morelli, E.A. “Real-Time Pilot Inputs for Aircraft Dynamic Modeling,” Session 4.1, Paper 1, *54th Annual International Symposium, Society of Flight Test Engineers*, Annapolis, MD, October 2023.



Flight Test Team



Credit: NASA Langley Research Center