



Real-Time Pilot Inputs For Aircraft Dynamic Modeling

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Credit: NASA Langley Research Center

Aircraft Dynamic Modeling



Credit: NASA Armstrong Flight Research Center

Procedure

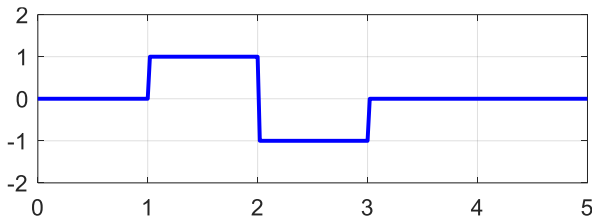
- 1) **Conduct an informative experiment**
- 2) Identify an adequate mathematical model structure
- 3) Find accurate values for the parameters in the model structure
- 4) Validate the model

Results can be used to analyze, predict, and control

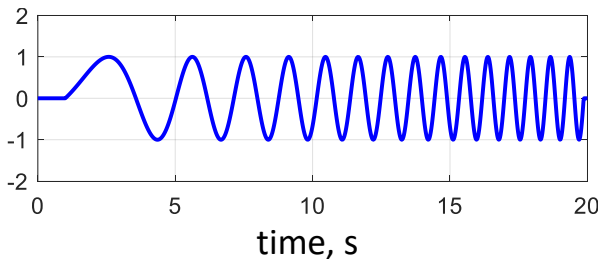
Excitation Inputs

Single-input (sequential):

Doublet

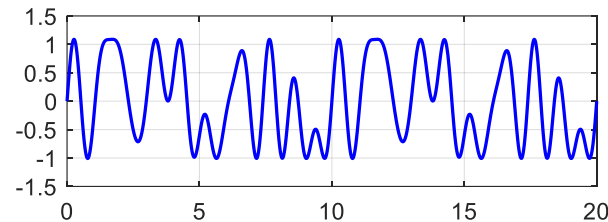


Frequency Sweep

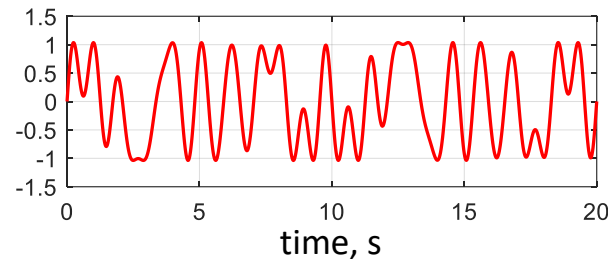


Multiple-input (parallel):

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



Flight Test Approaches



Conventional: Analyst Centric

- Preflight design of ideal single-input forms (multi-steps, frequency sweeps), including amplitudes, frequencies, and duration, for each flight condition
- Pilot training to reproduce ideal input forms
- Postflight analysis to evaluate the data quality
- Frequent repeats due to the imprecise approach

New: Pilot Centric

- Use real-time dynamic modeling and data plots to enable the pilot to discover efficient multi-axis inputs with proper amplitudes, frequencies, and duration
- No preflight input design or preflight pilot input training required
- Good data for accurate dynamic modeling is confirmed in real time

Aircraft Dynamic Modeling

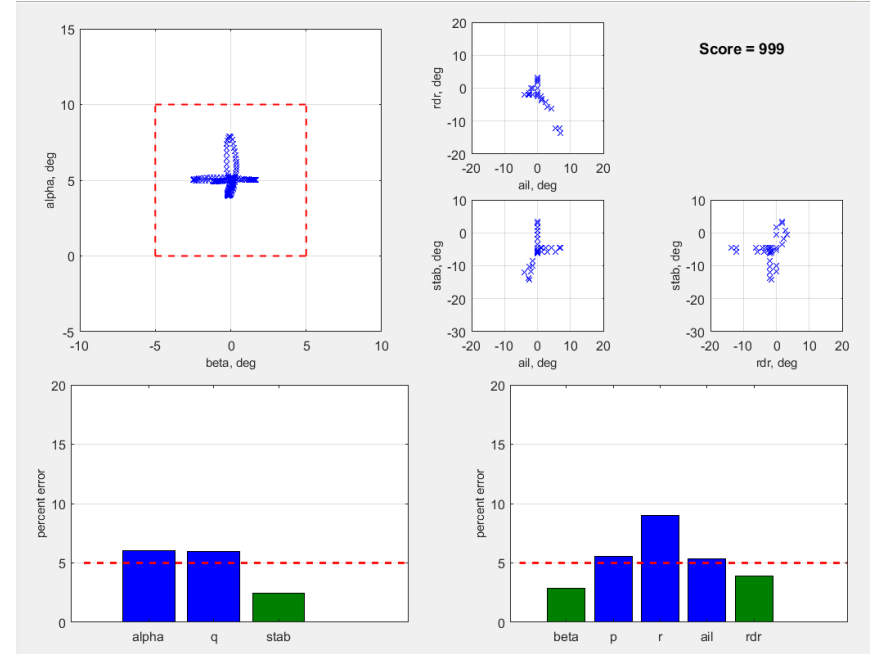
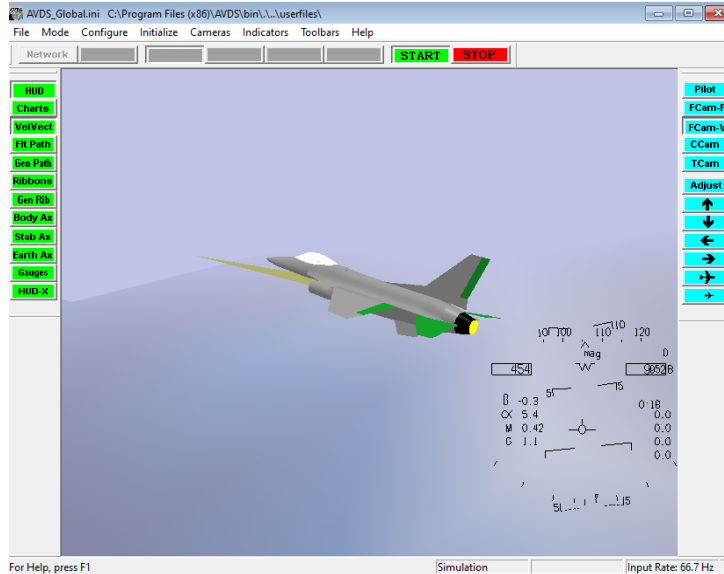
$$\dot{q} = \mathbf{M}_{\alpha} \Delta\alpha + \mathbf{M}_q \Delta q + \mathbf{M}_{\delta_s} \Delta\delta_s$$

$$\dot{p} = \mathbf{L}_{\beta} \Delta\beta + \mathbf{L}_p \Delta p + \mathbf{L}_r \Delta r + \mathbf{L}_{\delta_a} \Delta\delta_a + \mathbf{L}_{\delta_r} \Delta\delta_r$$

$$\dot{r} = \mathbf{N}_{\beta} \Delta\beta + \mathbf{N}_p \Delta p + \mathbf{N}_r \Delta r + \mathbf{N}_{\delta_a} \Delta\delta_a + \mathbf{N}_{\delta_r} \Delta\delta_r$$

- Linear dynamic models are sufficient for flight test data evaluation
- Parameter values and uncertainties can be computed in real time
- Practical and efficient calculations, successful in prior flight tests
- Real-time uncertainties indicate signal-to-noise and correlations

Real-Time Pilot Display



Maneuver to make the bars on the display (model parameter uncertainties) smaller than the target values shown, as quickly as possible, without exceeding the maneuver envelope limits for selected quantities (e.g., beta/alpha)

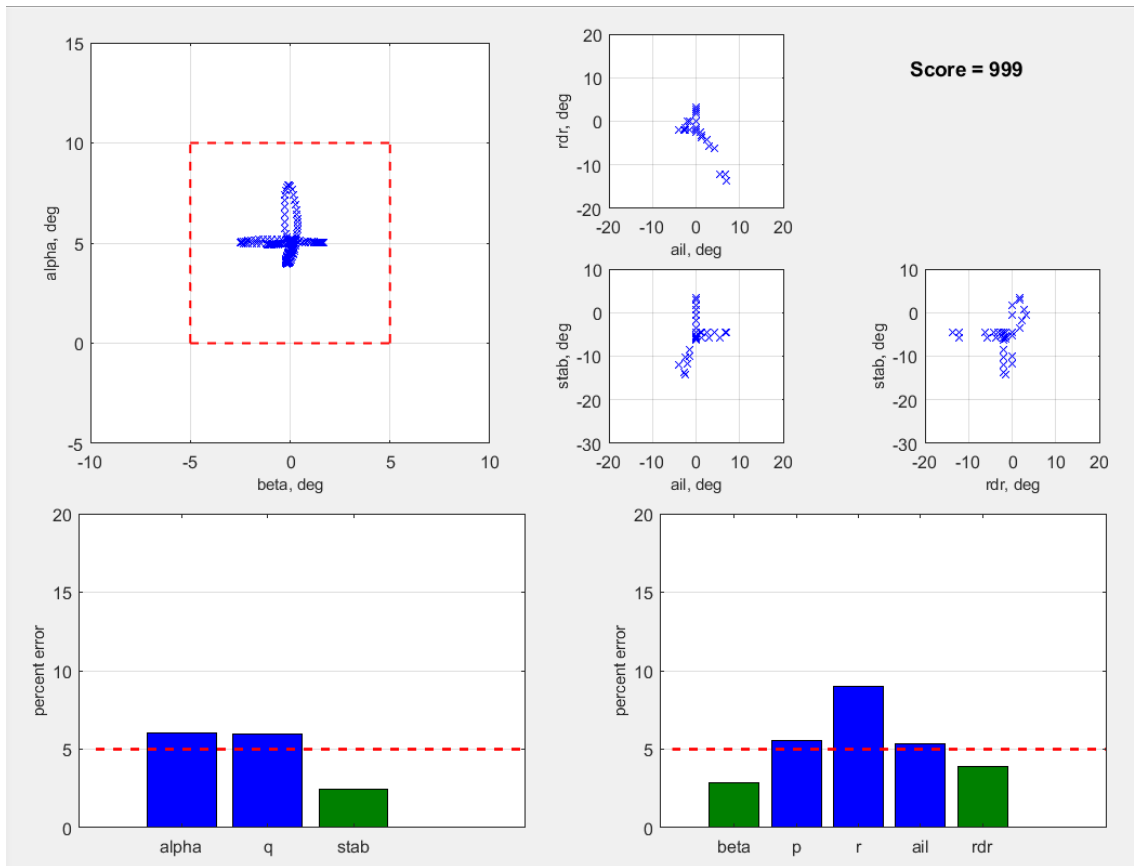


Maneuver Scoring

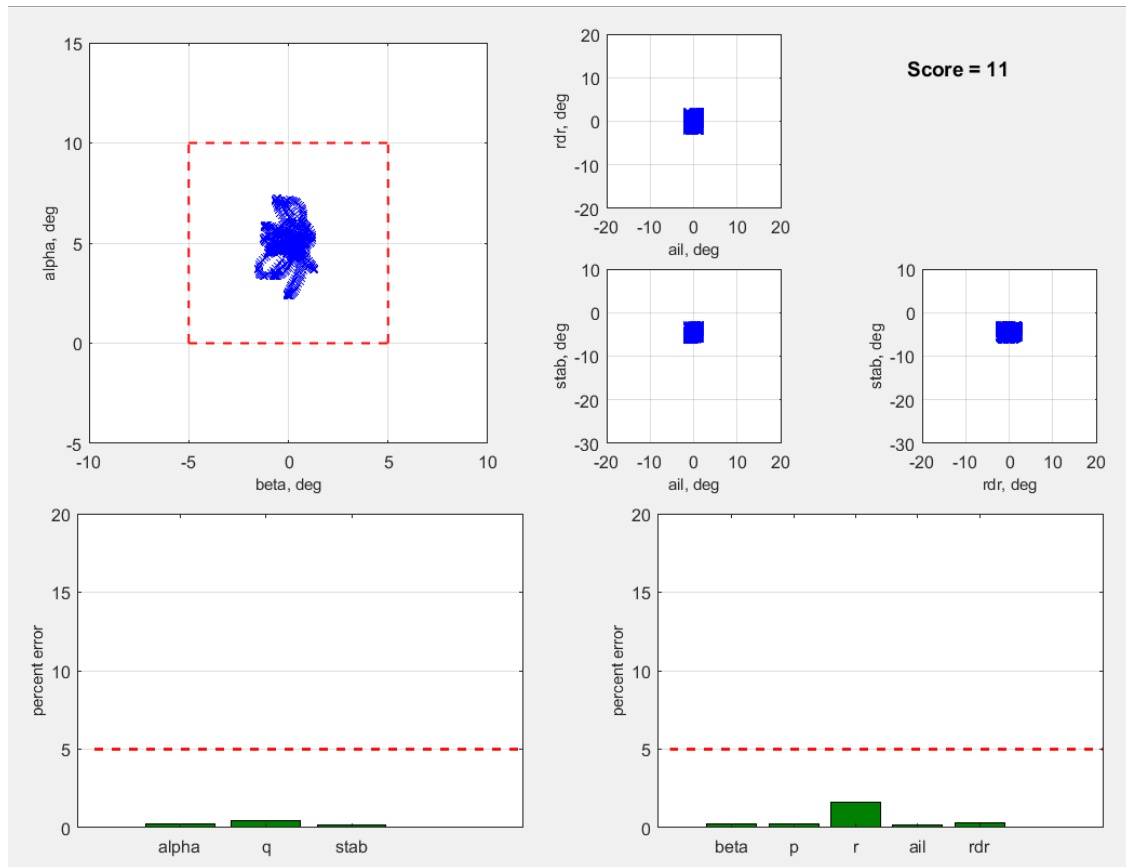
Score = (time to achieve all percent error goals)
+ (time outside the response boundaries)

- A lower score indicates a better maneuver
- Score is 999 if any percent error goal is not achieved

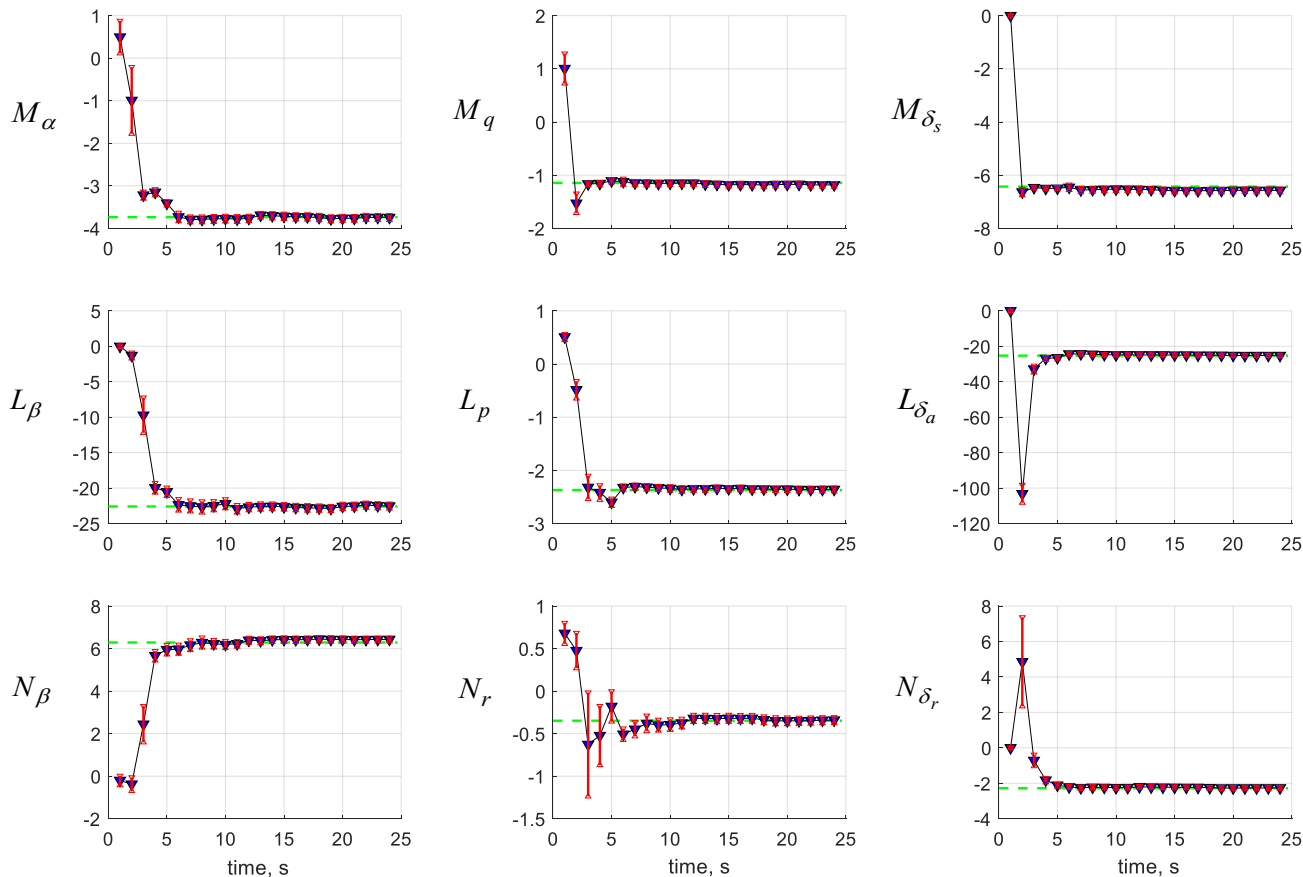
Inadequate Multi-Axis Maneuver



Successful Multi-Axis Maneuver



Successful Multi-Axis Maneuver



Demonstration

F-16



Credit: NASA Langley Research Center



Implementation



Real-Time Pilot Display:

- Shows dynamic modeling uncertainties compared to goals:
 - Enables pilot to intuitively discover effective multi-axis inputs
 - Identifies when to stop
- Indicates data deficiencies to be corrected
- Shows compliance with aircraft response constraints
- Takes the flight test engineer out of the loop

Flight Test Requirements:

- Real-time flight data at 25 Hz (e.g., using ethernet packets):
angular rates, control deflections, air flow angles
- Ruggedized cockpit computer running MATLAB®



Conclusions



- Pilot can use flying skills to achieve the goal for the flight test:
Efficiently collect informative multi-axis data for dynamic modeling
- No need for preflight input design or pilot training to implement inputs
- Benefits of multi-axis inputs can be achieved by a pilot
- No need for postflight analysis to certify the data for accurate modeling
- Approach can be applied to any aircraft at any flight condition
- Can also be used for closed-loop flying qualities models
- Can be used as a tool for test pilot training