



Objectives – Testing Handling Qualities Holistically

1. Provide update on FAA sponsored research used to inform policy
2. Describe new process that integrates development and TIA testing **Elements** and considers future automation growth
3. Explain how pilot ratings factor into overall assessments
4. Introduce research flight test guide that explains new testing approach

Simulator and National Campaign Handling Qualities Research

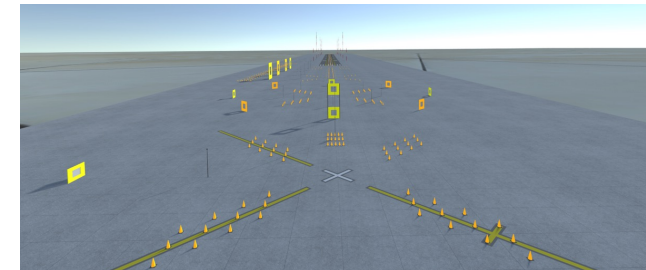
- Michael Feary, NASA AMES Principal Investigator

Adapting Mission Task Elements (MTE) for Civilian Operations

Handling Quality Task Elements (HQTE)

Goal:

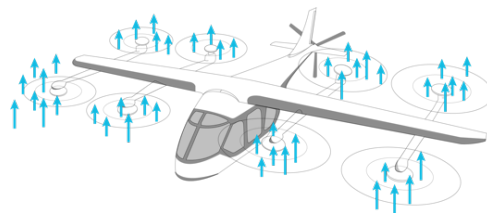
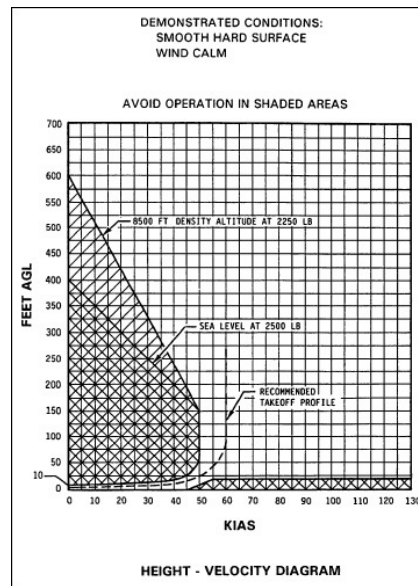
- Set up repeatable, operationally representative maneuvers that expose handling quality deficiencies
- Path to the future, increased automation capabilities
- Develop Foundational Capabilities
 - Aircraft Performance, Controls, Interfaces
- Define Testing Environment
 - Usable Cue Environment, Maneuver and Range description
- Metrics for Discussion of Handling Quality Ratings
 - Desired and Adequate performance criteria
 - Coverage for transitions and behavior



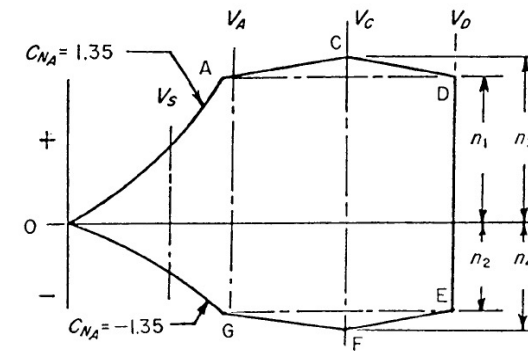
Evaluating Vertical Takeoff and Landing (VTOL) Aircraft

Physics Based Aircraft Behavior

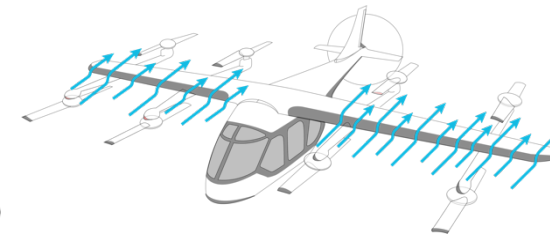
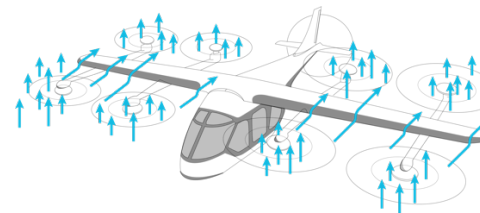
Thrust-borne aircraft behavior



Wing-borne aircraft behavior



Transitions



Evaluating Aircraft with Indirect Flight Controls

Interface

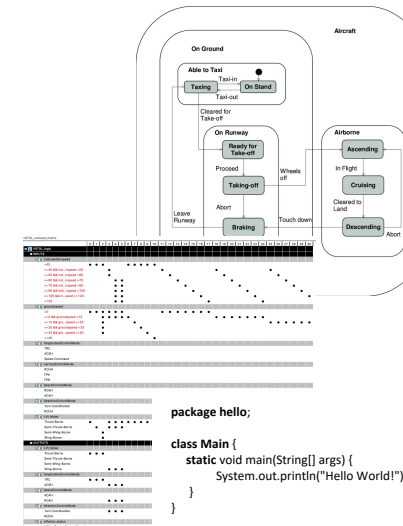


Inceptors



Displays

Software Based Aircraft Behavior



Indirect Flight Controls and Decision Logic

Evaluating VTOL aircraft with Indirect Flight Controls

Interface



Pilot/Operator
Requirements

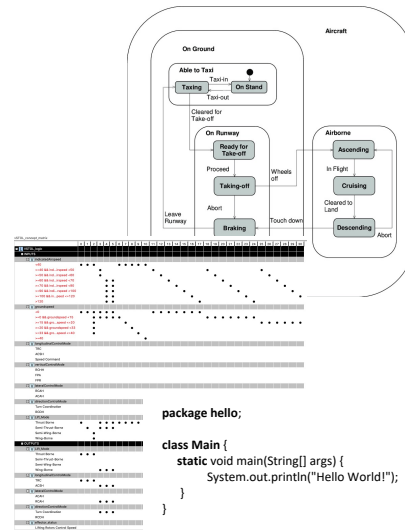
Inceptors



Displays

Software Based Aircraft Behavior

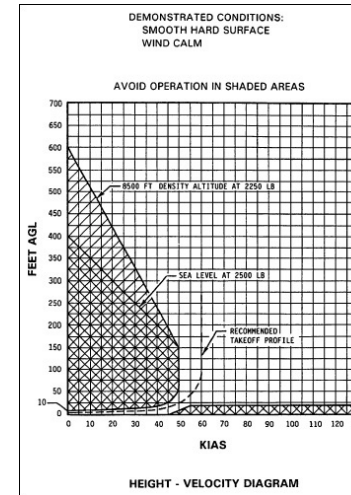
Indirect Flight Controls



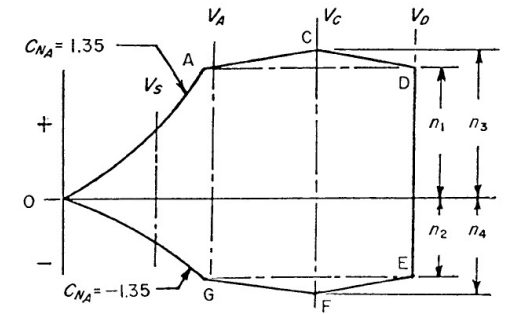
Indirect Flight Controls
and Decision Logic

Physics Based Aircraft Behavior

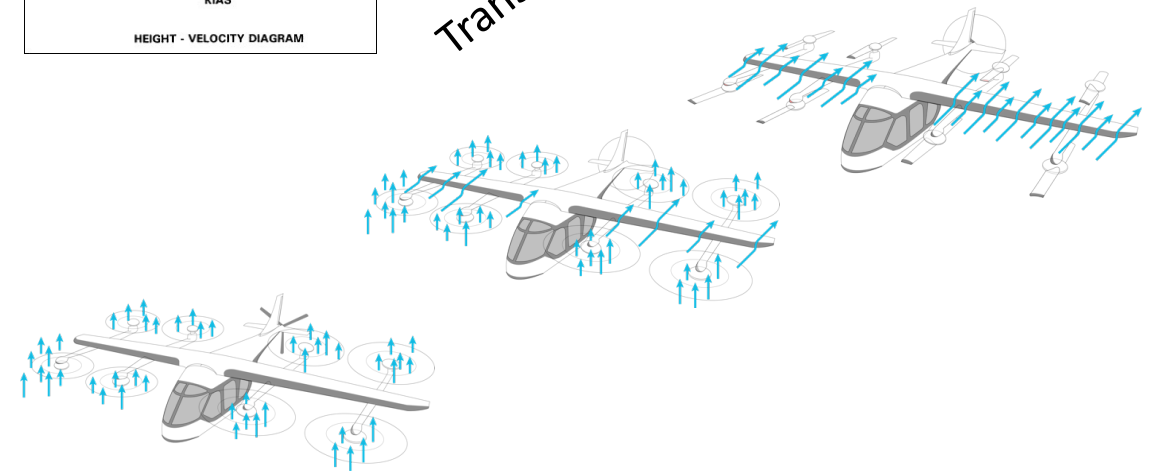
Thrust-borne
aircraft behavior



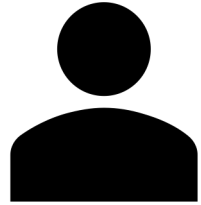
Wing-borne
aircraft behavior



Transitions



Evaluating VTOL aircraft with Indirect Flight Controls



Pilot/Operator Requirements

- Predictability
- “without requiring excessive concentration, skill, alertness or fatigue”
- Training requirements

Interface



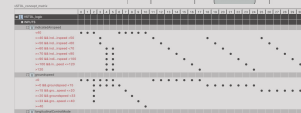
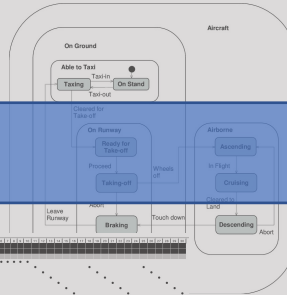
Inceptors



Displays

Software Based Aircraft Behavior

Indirect Flight Controls



```
package hello;

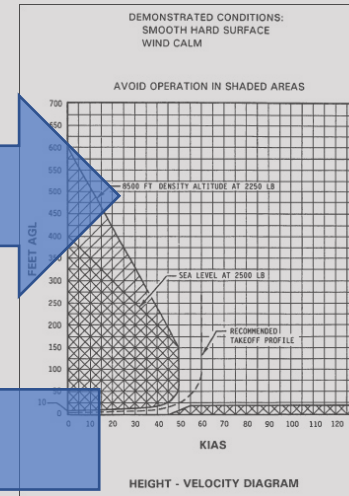
class Main {
    static void main(String[] args) {
        System.out.println("Hello World!");
    }
}

if (airspeed < 40)
{
    if (groundspeed > +00 && groundspeed < 15)
    {
        if (groundspeed > 15 && groundspeed < 25)
        {
            lift_mode = thrust;
            longitudinal_control_mode = TRC;
        }
    }
}
```

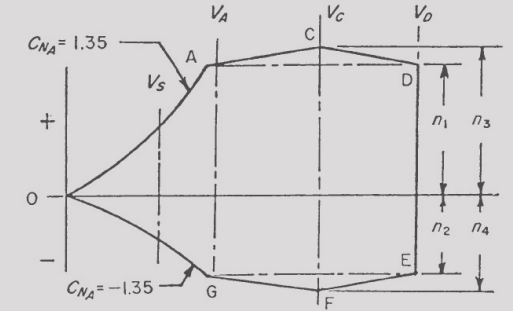
Indirect Flight Controls and Decision Logic

Physics Based Aircraft Behavior

Thrust-borne aircraft behavior



Wing-borne aircraft behavior



Transitions

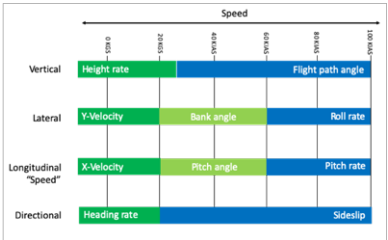


Aircraft Configuration Matrix

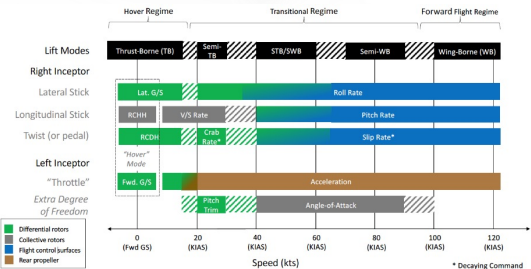
Aircraft and Propulsion Configuration



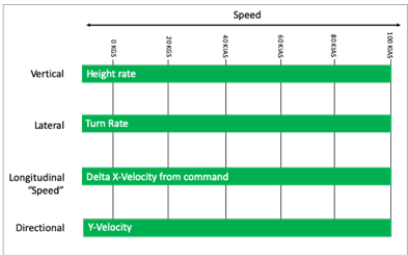
Flight Control Concepts



Conventional (RVLT)



Unified'



EZ-Fly''

Inceptor Mapping Concepts

Inceptor Mapping	DIM-0	DIM-1	DIM-2	SIM-1
Vertical "Altitude"	Lt. Stick Fore and Aft	Rt. Stick Fore and Aft	Lt. Stick Fore and Aft	Lt. Stick Fore and Aft
Directional "Heading"	Pedal/Twist	Pedal/Twist	Lateral "Side Slip"	Rt. Stick Fore and Aft
Longitudinal "Speed"	Rt. Stick Fore and Aft	Lt. Stick Fore and Aft	Rt. Stick Fore and Aft	Rt. Stick Rt and Left
Lateral "Side Slip"	Rt. Stick Rt and Left	Rt. Stick Fore and Aft	Pedal/Twist	Pedal/Twist

Display Concepts



Flight Path Centric



Pitch Centric



Other

Aircraft Configuration Matrix

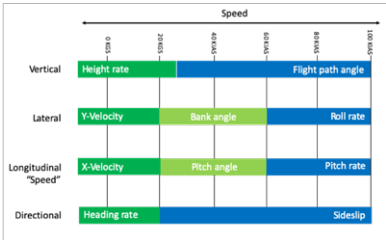
Aircraft and Propulsion Configuration



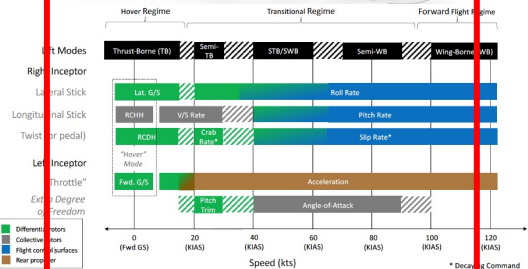
Quadrotor (Collective)
Lift + Cruise (RPM)



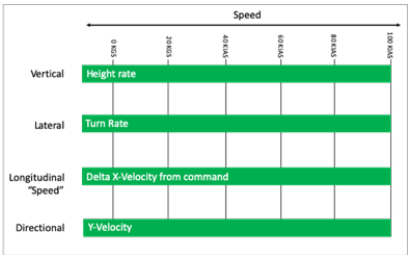
Flight Control Concepts



Conventional (RVLT)



Unified''



EZ-Fly''

Inceptor Mapping Concepts

Inceptor Mapping	DIM-0	DIM-1	DIM-2	SIM-1
Vertical "Altitude"	Lt. Stick Fore and Aft	Rt. Stick Fore and Aft	Lt. Stick Fore and Aft	Lt. Stick Fore and Aft
Directional "Heading"	Pedal/Twist	Pedal/Twist	Lateral "Side Slip"	Rt. Stick Fore and Aft
Longitudinal "Speed"	Rt. Stick Fore and Aft	Lt. Stick Fore and Aft	Rt. Stick Fore and Aft	Rt. Stick Rt and Left
Lateral "Side Slip"	Rt. Stick Rt and Left	Rt. Stick Fore and Aft	Pedal/Twist	Pedal/Twist

Display Concepts



Flight Path Centric



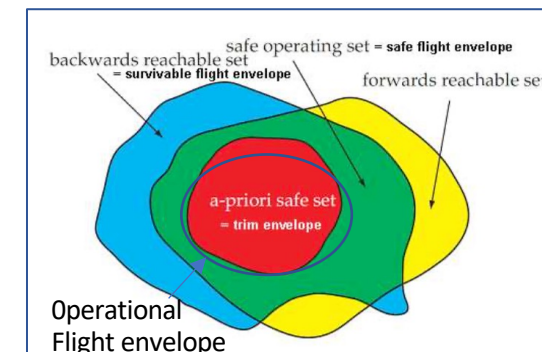
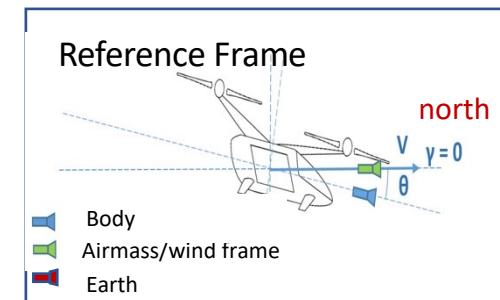
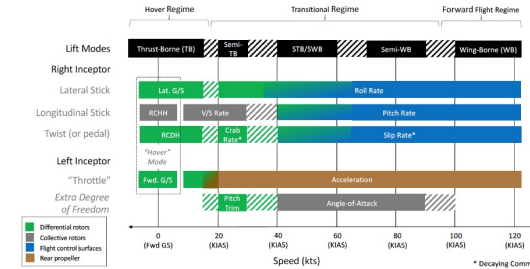
Pitch Centric



Other

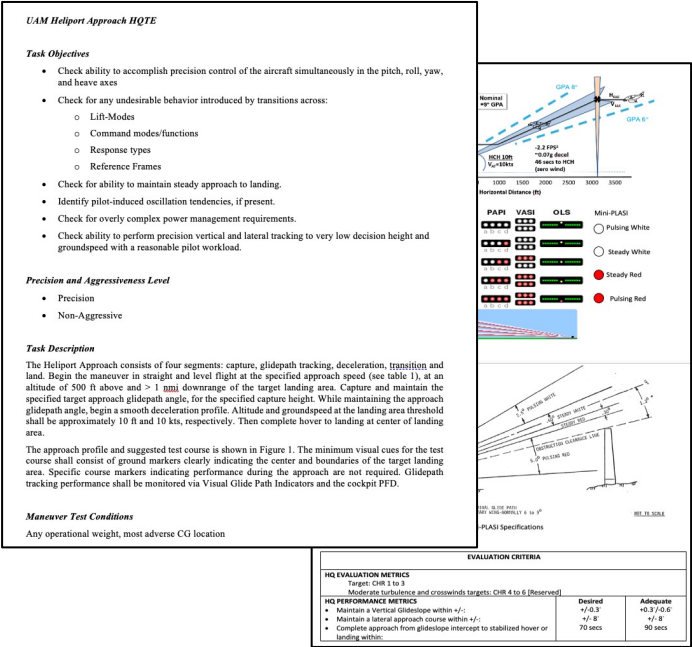
Transitions, Behavior and Evaluation Dimensions

- **Lift Mode**
 - Thrust – borne <> Wing-borne
- **Reference Frames**
 - Earth <> Airmass <> Body frame
- **Response Types**
 - e.g. Rate vs. attitude
- **Inceptors**
 - Motion and Effect of Cockpit Controls
- **Decision Logic**
 - Corner Cases
- **Envelope protection**
 - Behavior at transitions
- **OGE/IGE Behavior**
- **Dynamic Interfaces**

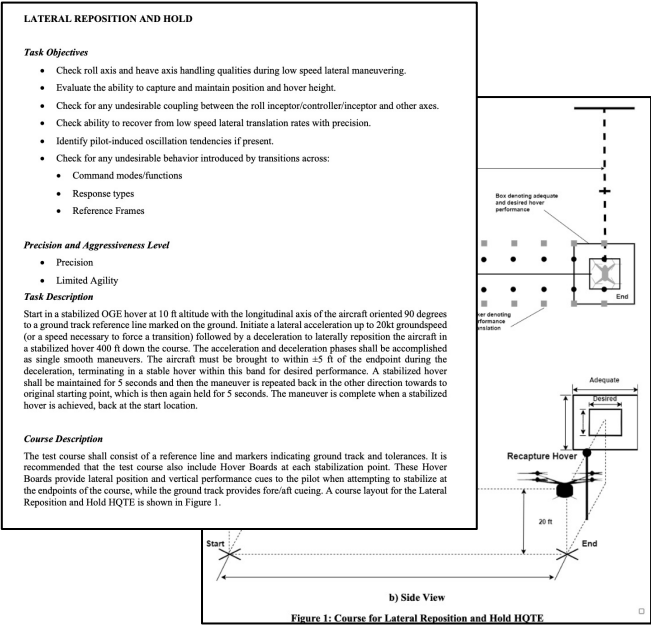


Operational Vs. Stress Test Maneuvers

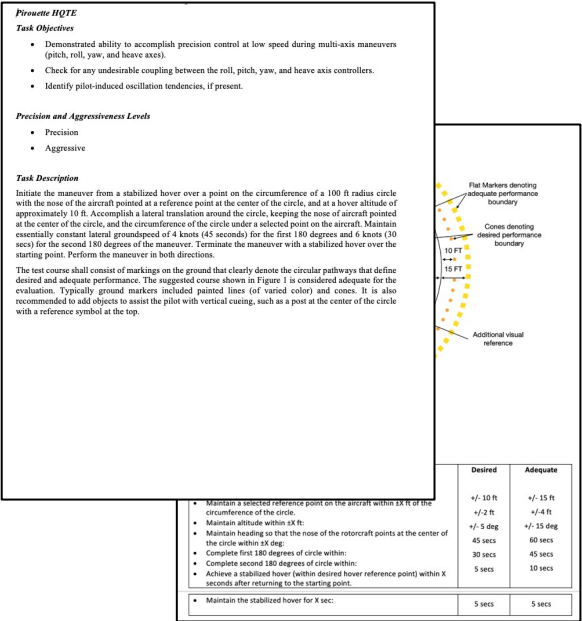
Heliport Approach



Lateral Reposition



Pirouette



* w/D. Webber – FAA/NASA National Campaign

Accomplished 3 Research Objectives and Foundation for FAA and NASA collaborative work

- **Foundational Simulator Capability**
 - Modifiable components – aircraft performance, controls, inceptors, displays
 - Connection to High Fidelity simulator platforms (e.g. Vertical Motion Simulator)
 - Engineering display to evaluate HQTE flight technical error
 - Platform designed for future automation development and evaluation
- **Industry representative VTOL aircraft with “Unified like” flight control system**
 - Collective control quadrotor
 - RPM controlled Lift + Cruise aircraft
- **Aircraft Control**
 - Modified aggressiveness levels during study
 - Examples for both adequate and inadequate handling
- **Test courses**
 - Developed virtual range requirements used for specific tasks
 - Visuals for NASA-FAA National Campaign ranges
- **Tested 54 HQTE conditions**
 - Low speed and Hover maneuvers, approaches
 - multiple Flight Test Pilot/Test Engineer pairs